Fisheries and Oceans Canada
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Canadian Science Advisory Secretariat (CSAS)

Research Document 2023/024

Newfoundland and Labrador Region

A Simple Mixed-Effects Model to Smooth and Extrapolate Weights-at-Age for 3Ps Cod

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March 2023

Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

Published by:

Fisheries and Oceans Canada
Canadian Science Advisory Secretariat
200 Kent Street
Ottawa ON K1A 0E6

http://www.dfo-mpo.gc.ca/csas-sccs/
csas-sccs@dfo-mpo.gc.ca

ISSN 1919-5044
ISBN 978-0-660-47975-0 Cat. No. Fs70-5/2023-024E-PDF

Correct citation for this publication:

Cadigan, N. 2023. A Simple Mixed-Effects Model to Smooth and Extrapolate Weights-at-Age for 3Ps Cod. DFO Can. Sci. Advis. Sec. Res. Doc. 2023/024. iv + 49 p.

Aussi disponible en français :

Cadigan, N. 2023. Un modèle à effets mixtes simple pour lisser et extrapoler les poids selon l'âge pour la morue présente dans la sous-division 3Ps. Secr. can. des avis. sci. du MPO. Doc. de rech. 2023/024. iv + 50 p.

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ABSTRACT

Good estimates of weight-at-age for fishery catches and the stock are necessary for more reliable stock assessment and projections. I use a simple model to filter out “noise” in the 3Ps cod weight-at-age estimates, and to fill in missing values, especially for older ages and the age 14+ group that will be used in assessment models for the stock. The weight model is applied to estimated weight-at-age from fishery monitoring activities and also weight-at-age from the Fisheries and Oceans Canada (DFO) Spring research vessel (RV) survey which are assumed to represent weight-at-age in the stock. The other important model inputs are information about the precision of sampling estimates of weight-at-age which the model uses to help distinguish between population variability and measurement error. The model fits the fishery weights-at-age closely for those ages with low measurement error coefficients of variation (CVs). The survey weights-at-age have more between-year variability and presumably higher CVs and therefore the model did not fit these data as well but did capture the overall trends in the weights-at-age over time.

INTRODUCTION

Some stock assessment models fit to observations of tonnes of landings among other data, and therefore to predict landings, these models require information on the average weight-at-age (Wa) of fish in the catch. Stock projections based on future fishing quota options (in tonnes) also require fishery Wa. Therefore, it is important to have good estimates of catch Wa for more reliable stock assessment and projections. Similarly, information on average Wa in the population is used to estimate stock biomass and spawning stock biomass (SSB), and measurement error in stock Wa will add measurement error to biomass and SSB estimates. Note that catch Wa may be different than stock Wa because of fishery size-selectivity, among other factors (e.g., Taylor et al. 2005; Schueller et al. 2014; Li and Wagner 2019; Goodyear 2019). However, the catch and stock Wa data available for stock assessments are often noisy, especially at older ages, with large between-year changes and occasional decreases in the Wa within a cohort (e.g., Cadigan 2016). Some of this variation is caused by measurement error and not by variation in population (catch or stock) Wa. In addition, Wa may be missing altogether in some years for older ages (see for example Figures 1a and 1b ages 17+). Statistical models are commonly used to address such problems.

Modified von Bertalanffy time-series cohort growth models have been used to improve Wa estimates for the stock assessment of cod in Northwest Atlantic Fisheries Organization (NAFO) Divisions 2J3KL (e.g., Cadigan 2016). A similar model is used to infer ages of tagged cod in 2J3KL based on their length and date of capture (Cadigan and Konrad 2016). The standard von Bertalanffy model does not fit the 2J3KL cod data well, which is why Cadigan (2016) and Cadigan and Konrad (2016) used various modifications of this growth model to improve the fit to the data. In preliminary and unreported analyses of 3Ps cod Wa data, I was unsuccessful in getting a good fit to the data using modified von Bertalanffy models. The reasons for the poor fits are interesting and seem to be related to a decline in 3Ps cod growth rates around ages 4–8.

In this paper I develop a mixed-effects “smoothing” model to filter out “noise” in the 3Ps cod Wa estimates, and to fill in missing values, especially for older ages including the age 14+ group that will be used in assessment models for the stock. The mixed-effects model does not make mathematical assumptions about the body growth rates of 3Ps cod like the modified von Bertalanffy models in Cadigan (2016) and Cadigan and Konrad (2016), and the advantages and dis-advantages of this are considered further in the Discussion. The Wa model is applied to estimated Wa statistics from fishery monitoring activities and Wa statistics estimated from the DFO Spring RV survey which are assumed to represent Wa in the stock. The other important model inputs are information related to the precision of input estimates of Wa which the model uses to help distinguish between population variability and measurement error.

METHODS

DATA

The number of years with fishery weight estimates by age is illustrated in Fig. 1a, and the input estimates of catch Wa are shown in Fig. 1b. Catch weight was estimated in only one year for ages 25 and 27 and these ages are not shown in Fig. 1b. These data are tabulated in Appendix IV and were obtained from DFO through a data request. The time trends at ages 3–6 are different than at older ages (also see Fig. 2). Also, frequently there are large between-year changes in Wa that may not reflect changes in the population Wa of the catch. There are many missing values, particularly for older ages. Other model inputs are the CVs for the estimated catch Wa (Fig. 3). These CVs are the same as the catch-at-age CVs that I was provided. It is straight-forward to show this using Equation (14) in Gavaris and Gavaris (1983). There is high between-year variability in CVs, and some very low CVs at older ages that do not seem reliable. Therefore, as a pragmatic solution I replaced the CVs with a 50–50 weighted average of the annual CV value for each age and the mean CV for the time-series at that age. This is a type of shrinkage estimation procedure. I used the shrinkage CVs (red lines in Fig. 3) in the catch Wa model. The 1993 CVs were all zero's so I replaced them with 95th percentiles of the CVs from other years.

I used the spring RV survey information to estimate stock Wa and motivation for this decision is provided in the Stock Wa section below. However, I was provided with a longer time-series of RV length-at-age (La) than Wa, so I based my Wa model on La and a length-weight relationship (see Stock Wa section). The La data are illustrated in Fig. 4. Different from the fishery Wa data, the decreasing trends in survey La are broadly similar at most ages (also see Fig. 5); however, similar to fishery Wa, there are large between-year changes in survey La that may not always reflect changes in stock La (Fig. 6).

There were too few commercial weights at age 1 to include these data in the model fitting. There is practically no fishery catches at age 1 so there is no need to estimate weight at this age. There were 10 or fewer years with weight estimates for ages >21 (Fig. 1a) and their CVs do not seem to be reliable (Fig. 3). The commercial weight statistics at age 22 seemed unusually low (Fig. 1b) compared to ages 20–21, although there was one high estimate for age 22 in 1990 that had high influence on model results in preliminary model fitting. The oldest age in the RV data is 21. Therefore, I decided to limit the commercial weight statistics used for model estimation to ages 2–21.

FISHERY CATCH WA MODEL

The model can be summarized as

$$\log(W_{ay}) = A + Y + C + A \times Y + \varepsilon,$$

where W_{ay} is the body weight (kg) at age *a* in year *y*, and the log-weight model is a linear function of an age-effect (A), a year-effect (Y), a cohort-effect (C), an age-year interaction ($A \times Y$), and a measurement error term (ε). The age-effect A is simply modelled as a free fixed-effect parameter for each age. *Y* is a random-effect assumed to have mean zero and AR(1) time-series correlation. *C* is also a random-effect with AR(1) time-series correlation across cohorts. A*Y are random-effects with separable AR(1) correlation by age and year, and ε is a residual error term with standard deviations fixed at the input CV values. The residual variance is not estimated by the Wa model. This is set equal to the CVs I was provided.

This model provides smoothed estimates of catch Wa. I do not recommend this model to estimate stock Wa. This is because the catch Wa will over-estimate the weight of young fish in the stock because of the length-selectivity of the gears used in the 3Ps cod fishery. There is a potential that commercial Wa will under-estimate the weight of old fish recently because of the domed selectivity pattern of gillnets which will have low selectivity for large, old fish. Gillnets may only catch the smaller-sized fish at older ages. Gillnets are now the dominant gear used in the 3Ps cod fishery (e.g., Ings et al. 2019); however, this has not always been the case. The spring survey should have good selectivity for a large range of cod sizes (i.e., 20 cm+) and therefore provide better estimates of Wa in the stock compared to commercial weights. Also, the RV survey occurs in the spring about the time when cod are beginning to spawn in 3Ps and RV-based stock Wa should represent weight at the time of spawning.

STOCK WA

The survey Wa data are modelled somewhat similar to the fishery Wa data. I first fit a survey La model and then derived stock Wa using the La and a weight-length relationship that I also estimate.

The survey length-at-age (La) model is

$$\log(L_{ay}) = A + Y + C + A \times Y + \varepsilon,$$

I was not provided the La CVs. Another modelling difference is that I inferred these CVs for the annual estimates of La using data on the number of otoliths examined each year (*n*) and an "expert opinion" assumption that the CV for the distribution of population La is 30%. With these assumptions, I approximated the CV of the annual estimate of mean La as $CV = 0.3/n^{0.5}$. I used these values for $SD(\varepsilon)$. I think the flexible smoothing model has limited capability of distinguishing between measurement error and population variability which is why I prefer to fix the measurement error CV at sample estimates. Since these were not available to me, I inferred these using the number of otoliths approach, although an obvious research recommendation is to include sample CVs in future model fitting.

I estimate stock Wa from La and weight-at-length (Wl). I estimated a log-linear weight ~ length relationship to estimate Wl. However, in preliminary analyses I found that a simple log-linear model (intercept = -12.16, slope = 3.13) did not have as good of a fit as expected and the model slightly underestimated the weights at small and large lengths. The slope of log(weight) versus log(length) was a little higher at larger lengths. I accounted for this using a segmented linear regression model which I implemented using the "segmented" package in R (Muggeo 2008).

PLUS GROUP

I use a common method to estimate the plus group Wa. The stock assessment for 3Ps cod has a plus group at age 14, and we need information on Wa at older ages to estimate the average 14+ Wa. I estimate a population abundance-weighted average Wa for ages 14–21 by assuming a steady-state age distribution based on a total mortality rate of Z=0.4; that is,

$$\bar{W}_{14+} = \frac{\sum_{i=0}^{7} W_{i+14} \exp(-0.4i)}{\sum_{i=0}^{7} \exp(-0.4i)},$$

where $\bar{W}_{14+}$ is the plus group average weight (kg) and W_{i+14} is the body weight (kg) of fish aged 14–21 (i.e., a = 14 + i, i=0,…,7). Age 21 is the oldest age I estimate catch or stock weights for, and there should be few survivors in the catch or stock populations at older ages, so the plus group weights should be reasonable. The assumption of Z=0.4 seems reasonable for 3Ps cod, but it is straight-forward to use better values if they are available. In fact, the plus group weight calculation could be included as part of the assessment model; that is, this Wa could be computed internally using assessment values for Z each year. However, this may be an option with little impact. The steady-state age distribution assumption will not account for the impact of cohort-size variations at plus group ages, nor any effects of differential fishery selectivity at these ages. However, for 3Ps cod it is anticipated that the 14+ abundance will be relatively low and assessment results should not be sensitive to how the plus group average weight is calculated.

ESTIMATION

Both models for Wa are mixed-effects models. I used marginal maximum likelihood to estimate the fixed effects parameters. This involves integrating the random effects out of the joint likelihood of the data and random effects. I used the TMB (Kristensen et al. 2016) package in R (R Core Team 2018) for this purpose, and then estimated the fixed effects parameters using the nlminb() function in R. TMB provides empirical Bayes predictions of the random effects which I used to predicted Wa for 1974–2017 and ages 3-21 for the fishery, and 1972–2018 and ages 1–21 for the survey. The C++ template code used by TMB is provided in Appendix III for the fishery Wa model. The code for the survey La is the same.

RESULTS

FISHERY CATCH WA

Parameter estimates and their standard errors are shown in Table 1. The gradient values are also included; these values should be close to zero in absolute value if the model is converged. Note that the standard errors were NA's for the estimates of the log of std (σ_Y) and its logit correlation. This is because $\sigma_Y \approx 0$ and a large range of small negative values give practically the same result.

The estimated *A* and *A**Y* model effects were most important for 3Ps cod (Fig. 7 and 8). The standard deviation of the random *A**Y* effects was $\sigma_{a\times y} \approx 0.168$, while $\sigma_{cohort} \approx 0.071$ and $\sigma_{year} \approx 0$. The *A**Y* effects reflect the different trends in weights at younger and older ages. *Y* effects were negligible, and the *C* effects were small. The model fit the annual Wa estimates very well (Fig. 9) and practically interpolated Wa for well-sampled ages with low CVs (i.e., ages 5–8; see Fig. 3), except for years when there were unusually abrupt changes (e.g., age 6 in 1997). However, there is smoothing at age 3 and older ages where the input CVs are higher, and the smoothing seemed reasonable. There were no residual patterns (Figs. 10 and 11).

I use the model to predict catch Wa for 1974–2017 and ages 3–21. The predictions for older ages were used to derive the 14+ Wa using an abundance weighted-average based on an assumed equilibrium age distribution and Z=0.4. The average Wa for 1974–78 was used to extrapolate Wa during 1959–73 when no data was available (Fig. 12). This was required for the 3Ps cod stock assessment models, which include catch-at-age data from 1959 to the present. The fishery Wa in Fig. 12 are what I propose for the 3Ps cod stock assessment. Values are provided in Appendix IV.

STOCK WA

Recall that I estimate stock Wa from La and Wl. I estimated a segmented log-linear weight ~ length relationship to estimate Wl. The model fit (Fig. 13) estimated the break-point in weight ~ length at about 44 cm.

The stock La model parameter estimates and their standard errors are shown in Table 2. The age effects and predicted random year and cohort effects are shown in Fig. 14, and the random *A**Y* effects are shown in Fig. 15. The interaction effects have different patterns in Fig. 15 and Fig. 8 (catch weight-age model). Similar to the catch Wa model, the RV La model resulted in negligible year effects (Fig. 14). However, the RV La model had much larger cohort effects compared to the catch Wa model results (compare Figs. 7 and 14). Although $\sigma_{cohort} \approx 0.071$ for the catch Wl model and $\sigma_{cohort} \approx 0.042$ for the survey La model, the cohort autocorrelation in length-age is much higher in Table 2 (0.88) than that of the weight-age model in Table 1 (0.47) which allows for larger La cohort-effects.

The La model did not fit the data (Fig. 16a) as closely as the catch Wa model (Fig. 9) because of higher input measurement error CVs in survey mean La, and higher between-year variability in the estimates of mean La, especially at ages 1–3 and older ages. However, the fits by cohort seemed reasonable (Fig. 16b) and there were no substantial La residual patterns (Figs. 17 and 18).

I use the La and Wl models to predict stock Wa for 1972–2017 and ages 1–21. The predictions for older ages were used to derive the 14+ stock average Wa, similar to catch Wa. The average Wa for 1972–76 was used to extrapolate Wa during 1959–71 when no data was available (Fig. 19). I was also provided with survey Wa values for 1978–2018 - a shorter series than the La I was provided. I included the Wa values in Fig. 19 for comparison purposes, but the model was not fit directly to these values. The model predicted stock Wa in Fig. 19 are what I propose for the 3Ps cod stock assessment. Values are provided in Appendix IV.

COMPARISON OF CATCH AND STOCK WA

A comparison of model-predicted catch and stock Wa's (Fig. 20) indicate that:

1. Catch Wa>>Stock Wa at younger ages, presumably because of growth between the time of the spring survey in 3Ps and the primarily summer-to-fall fishery, and also because of fishery selectivity.
2. Catch Wa ≈ Stock Wa for older ages (i.e., 9–13), which makes sense because weights at older ages will be less affected by seasonal growth and fishery selectivity.
3. There is some evidence that the 14+ average catch weights are less than the stock weights, presumably because of a dome-shaped fishery selectivity pattern.
4. The recent (since 1990s) time-trends in catch and stock Wa's are substantially different at ages 3–6. These differences are an important assessment issue to resolve.

DISCUSSION

The 2019 3Ps cod framework process decided to use the individual estimated values of fishery Wa and not the model estimated values. Since, the fishery Wa model fit the individual values fairly closely, this decision probably would have little impact on assessment results. The framework meeting decided to use the model-estimated stock Wa.

The input CVs for the survey La values are high and the model predictions could differ substantially from the survey values. The population variability of La was assumed to have a CV=30% to derive input measurement error CVs in the stock La model. This was only based on my experience fitting individual growth data for other species. Clearly more realistic values will improve estimation of stock Wa. I do not think the simple smoothing model approach could reliability differentiate between measurement error variability and changes in La over time and age. My analyses suggest that uncertainty about stock Wa is significant and more research is required to better estimate stock Wa for the assessment, and also understand why the time-trends in fishery and stock Wa are so different at ages 3–6.

The mixed-effects model does not make mathematical assumptions about the body growth rates of 3Ps cod like the modified von Bertalanffy models in Cadigan (2016) and Cadigan and Konrad (2016). A drawback of the simple model in this paper compared to von Bertalanffy growth models is that the simple model approach cannot be used to extrapolate weights at ages not included in the model. Age effects are separate fixed effects, and to extrapolate beyond the range of ages in the model, the age effects would also need to be some type of function of age.

It would be more effective to model individual length, weight and age data rather than averages like in this paper. This would better account for between-individual variability and sampling variability. A spatiotemporal growth model similar to Zheng et al. (2020) may provide a better understanding of differences in fishery and stock Wa.

ACKNOWLEDGEMENTS

Research funding was provided by the Ocean Frontier Institute, through an award from the Canada First Research Excellence Fund. Research funding was also provided by the Ocean Choice International Industry Research Chair program at the Marine Institute of Memorial University of Newfoundland. I thank the stock assessment science staff of Fisheries and Oceans Canada at the Northwest Atlantic Fisheries Science Center and scientists at the Center for Fisheries Ecosystems Research of Memorial University of Newfoundland for many discussions and contributions that assisted in the development of this paper.

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APPENDIX I – TABLES

Table 1. Parameter estimates (Est), standard errors (SD), and gradients (GRD) of the fishery Wa model. The negative log-likelihood is nll = -201.62, nparm = 26, AIC = -351.25, BIC = -232.08. eff indicates age effects.

Effect Name	Est	SD	GRD
eff_3	-0.508	0.072	-0.000083
eff_4	-0.141	0.069	0.000119
eff_5	0.280	0.069	0.000266
eff_6	0.625	0.069	-0.000148
eff_7	0.857	0.069	-0.000126
eff_8	1.074	0.069	-0.000240
eff_9	1.290	0.070	0.000356
eff_10	1.506	0.071	-0.000065
eff_11	1.700	0.072	-0.000050
eff_12	1.846	0.075	0.000006
eff_13	2.006	0.077	0.000004
eff_14	2.168	0.079	0.000082
eff_15	2.273	0.086	-0.000018
eff_16	2.472	0.095	0.000049
eff_17	2.553	0.107	-0.000032
eff_18	2.602	0.100	-0.000077
eff_19	2.803	0.102	-0.000007
eff_20	2.826	0.141	-0.000005
eff_21	2.912	0.151	0.000011
log_std_Y	-11.668	NA	0.000000
log_std_C	-2.640	0.290	0.000050
log_std_A*Y	-1.782	0.102	-0.000006
logit_ar_Y	1.362	NA	-0.000000
logit_ar_C	-0.120	1.169	-0.000015
logit_ar_A:A*Y	2.116	0.252	0.000036
logit_ar_Y:A*Y	1.230	0.277	-0.000018

Table 2. Parameter estimates (Est), standard errors (SD), and gradients (GRD) of the stock La model. The negative log-likelihood is , nll = -760.04, nparm = 28, AIC = -1464.09, BIC = -1336.14. eff indicates age effects.

Effect Name	Est	SD	GRD
eff_1	2.484	0.033	-0.000023
eff_2	3.063	0.030	-0.001080
eff_3	3.450	0.029	0.000503
eff_4	3.723	0.028	-0.000671
eff_5	3.903	0.028	0.001221
eff_6	4.025	0.027	-0.000366
eff_7	4.123	0.027	0.000217

Effect Name	Est	SD	GRD
eff_8	4.205	0.027	-0.000577
eff_9	4.293	0.027	-0.001133
eff_10	4.372	0.027	0.001233
eff_11	4.431	0.028	-0.000214
eff_12	4.500	0.030	0.000266
eff_13	4.546	0.033	-0.000024
eff_14	4.598	0.036	-0.000365
eff_15	4.645	0.040	0.000294
eff_16	4.689	0.042	0.000393
eff_17	4.727	0.053	-0.000189
eff_18	4.782	0.060	0.000016
eff_19	4.753	0.088	-0.000001
eff_20	4.792	0.081	0.000048
eff_21	4.796	0.112	0.000101
log_std_Y	-8.964	83.135	-0.000009
log_std_C	-3.171	0.429	-0.000016
log_std_A*Y	-3.342	0.267	0.000004
logit_ar_Y	-0.022	146.106	0.000015
logit_ar_C	2.022	1.067	0.000026
logit_ar_A:A*Y	2.828	0.820	0.000018
logit_ar_Y:A*Y	0.836	1.019	-0.000011

APPENDIX II – FIGURES

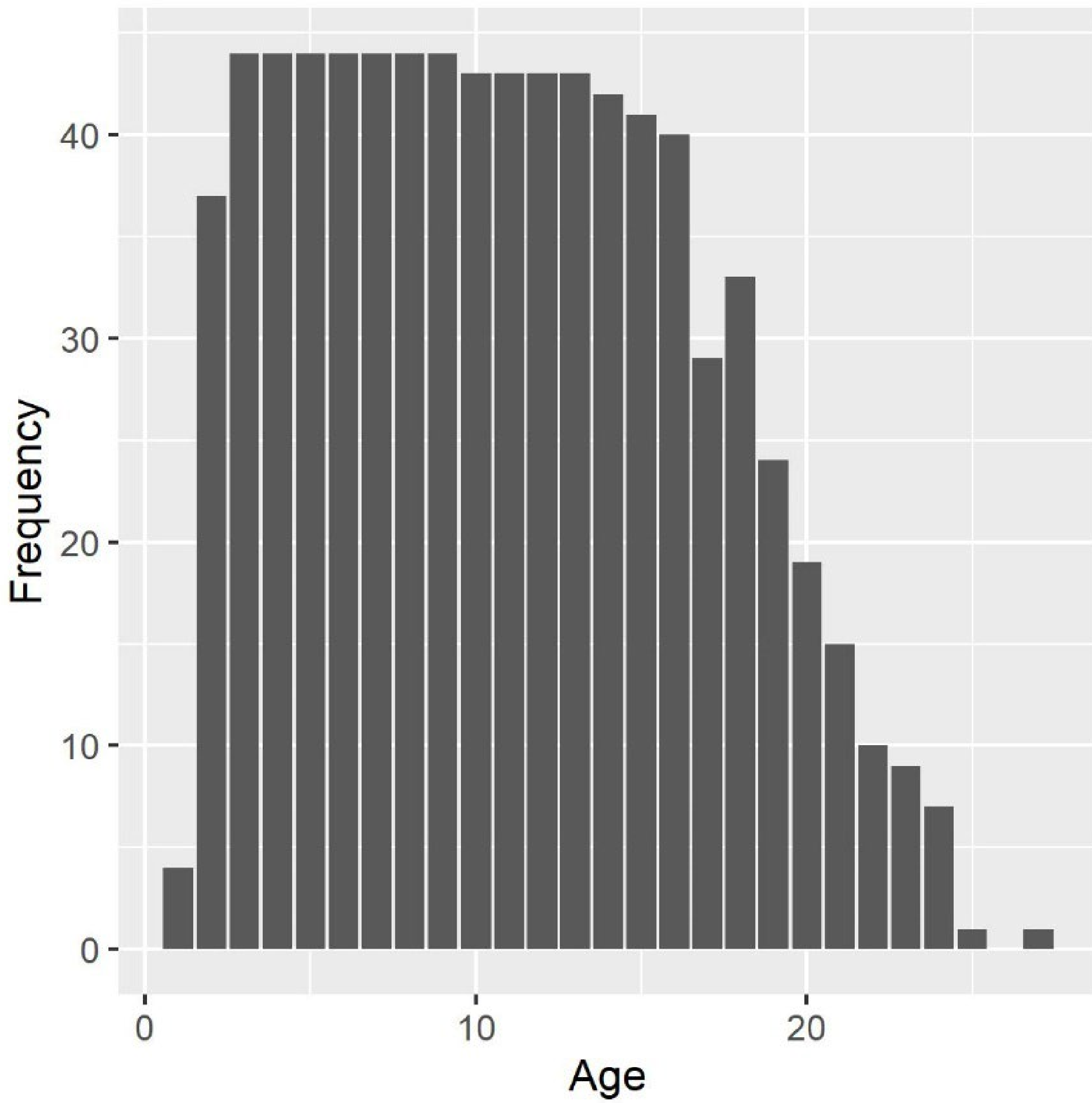

Figure 1a. Number of years with weight estimates for each age.

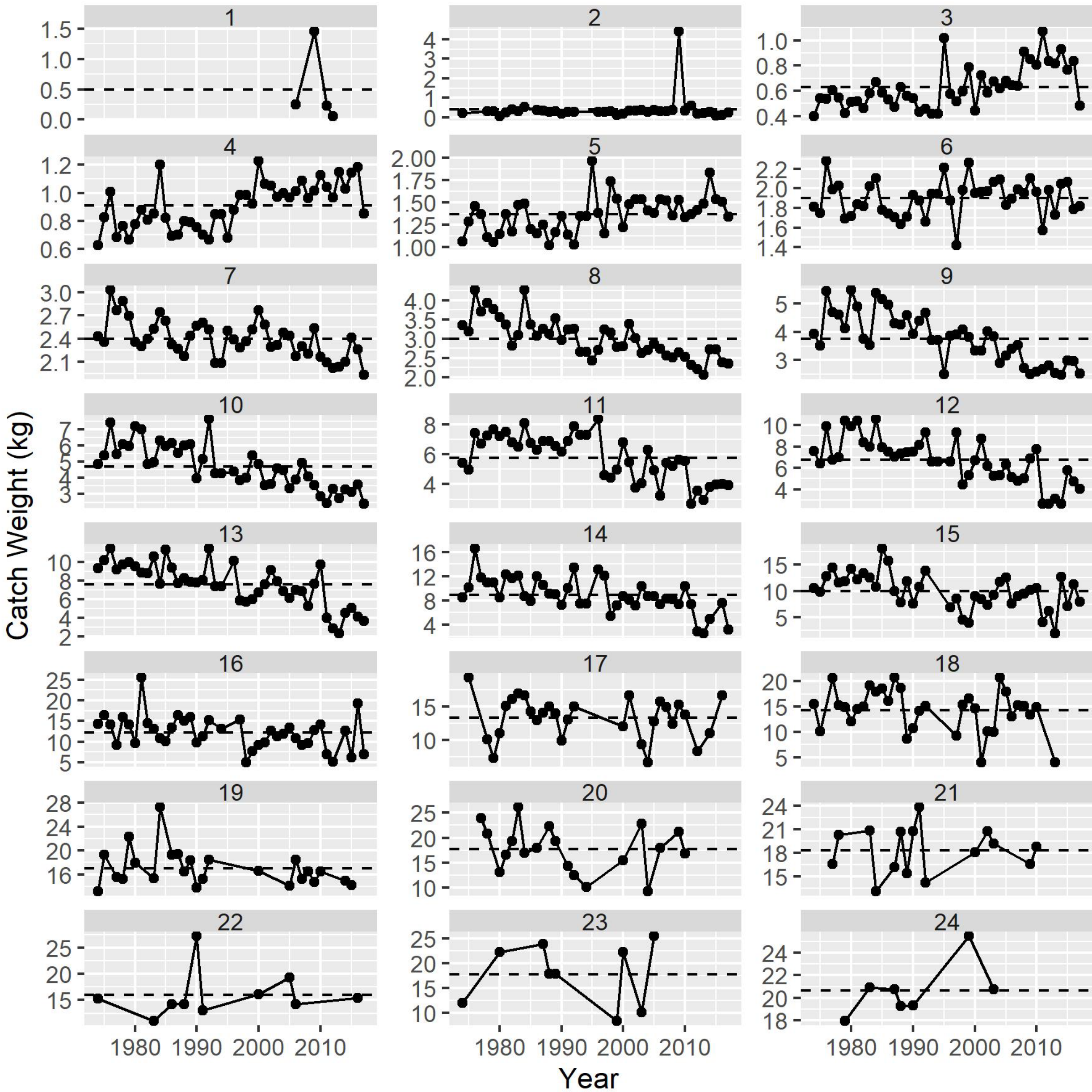

Figure 1b. Estimated average weight-at-age in fishery catches. Ages are listed at the top of each panel. Horizontal dashed lines indicate the series average for each age.

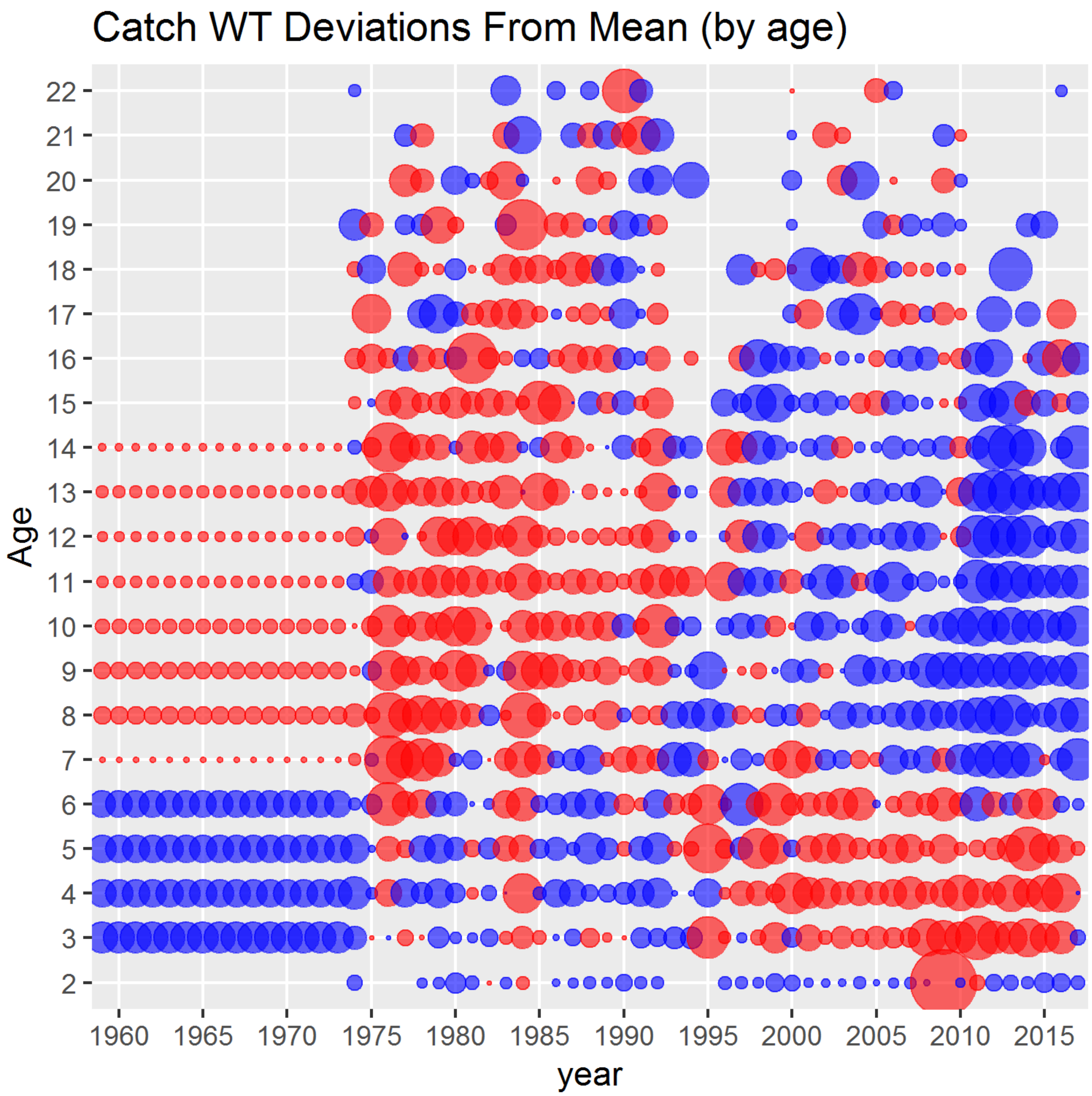

Figure 2. Deviations in catch weight-at-age. Bubble area indicates the absolute value of the deviation. Red indicates a positive deviation and blue indicates a negative deviation. Missing values have no bubble.

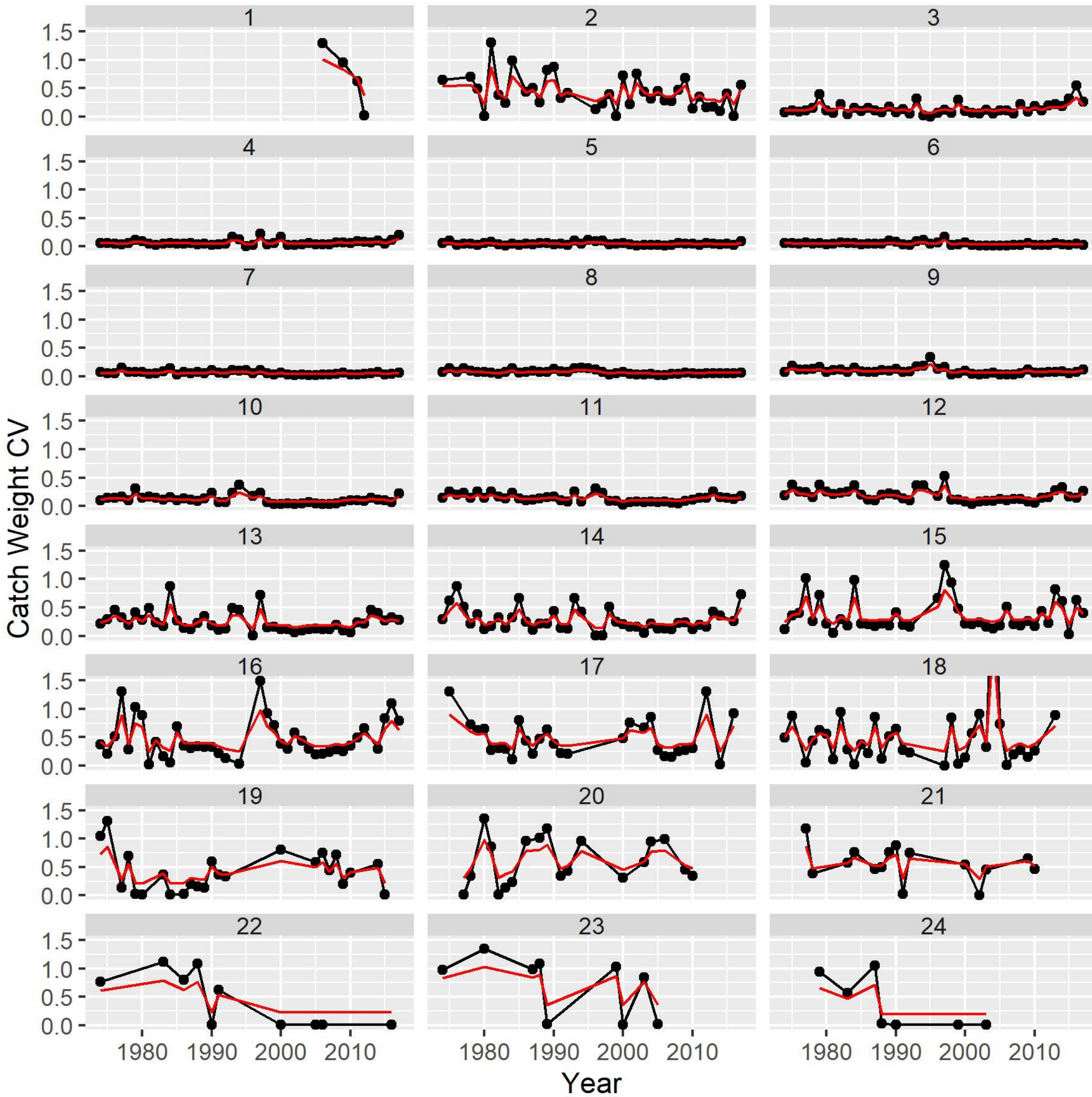

Figure 3. Coefficients of variation (CVs) in catch weight-at-age (black lines). Ages are listed at the top of each panel. Red lines indicate CVs that have been “shrunk” to the mean (see text for details).

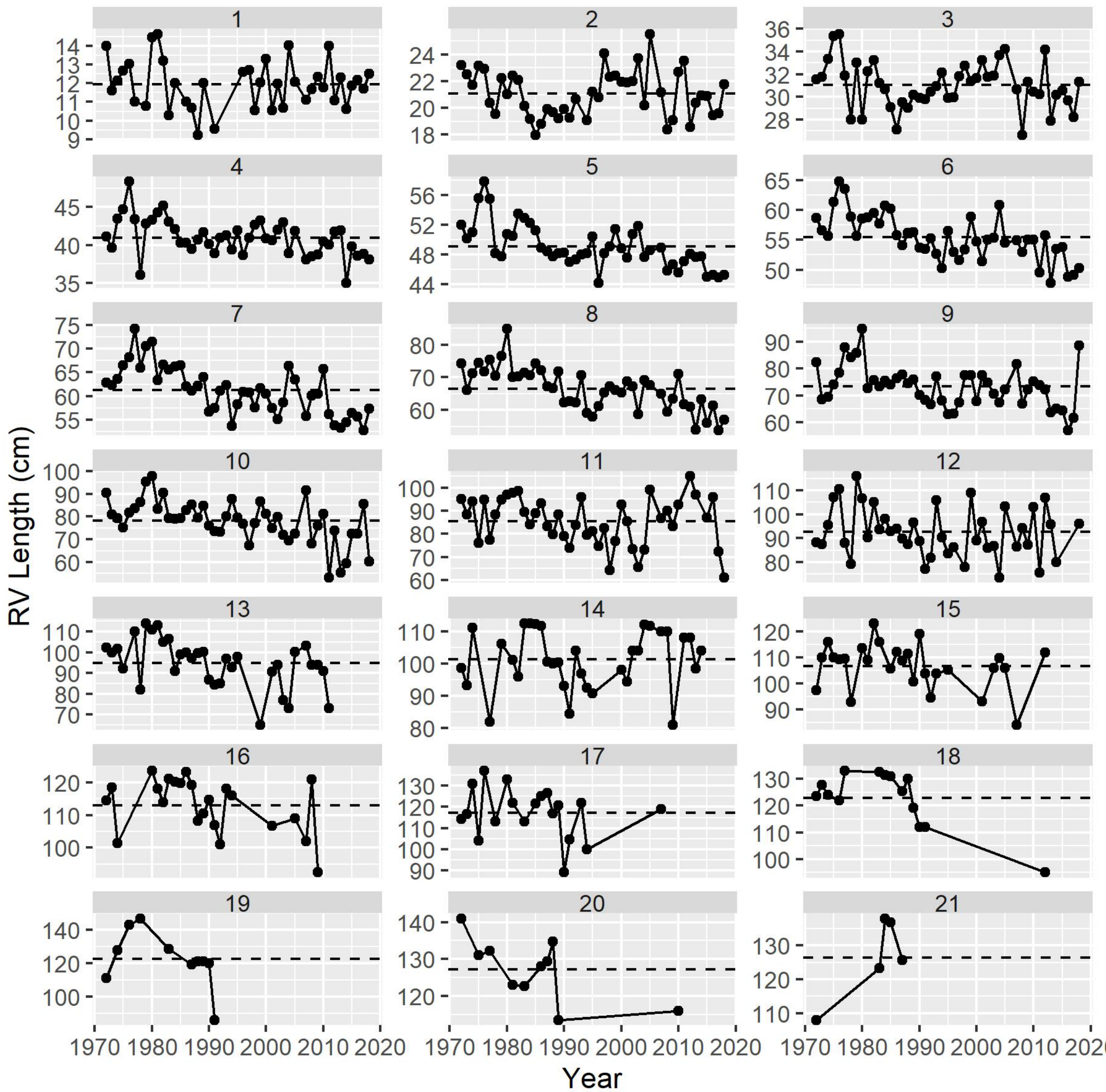

Figure 4. Estimated average length-at-age of cod from the DFO RV survey catches in 3Ps. Ages are listed at the top of each panel. Horizontal dashed lines indicate the series average for each age.

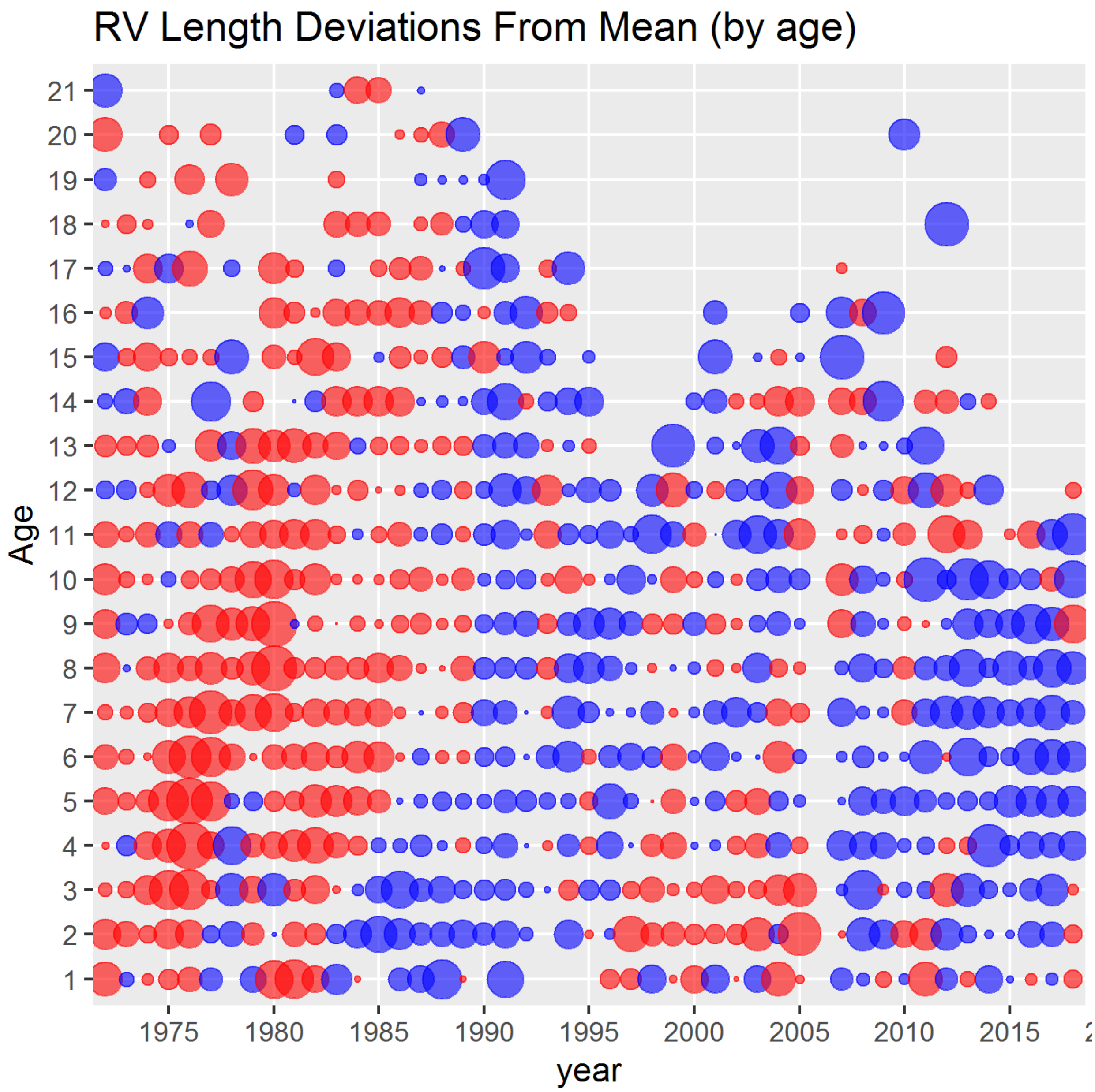

Figure 5. Deviations in DFO RV cod length-at-age. Bubble area indicates the absolute value of the deviation. Red indicates a positive deviation and blue indicates a negative deviation. Missing values have no bubble.

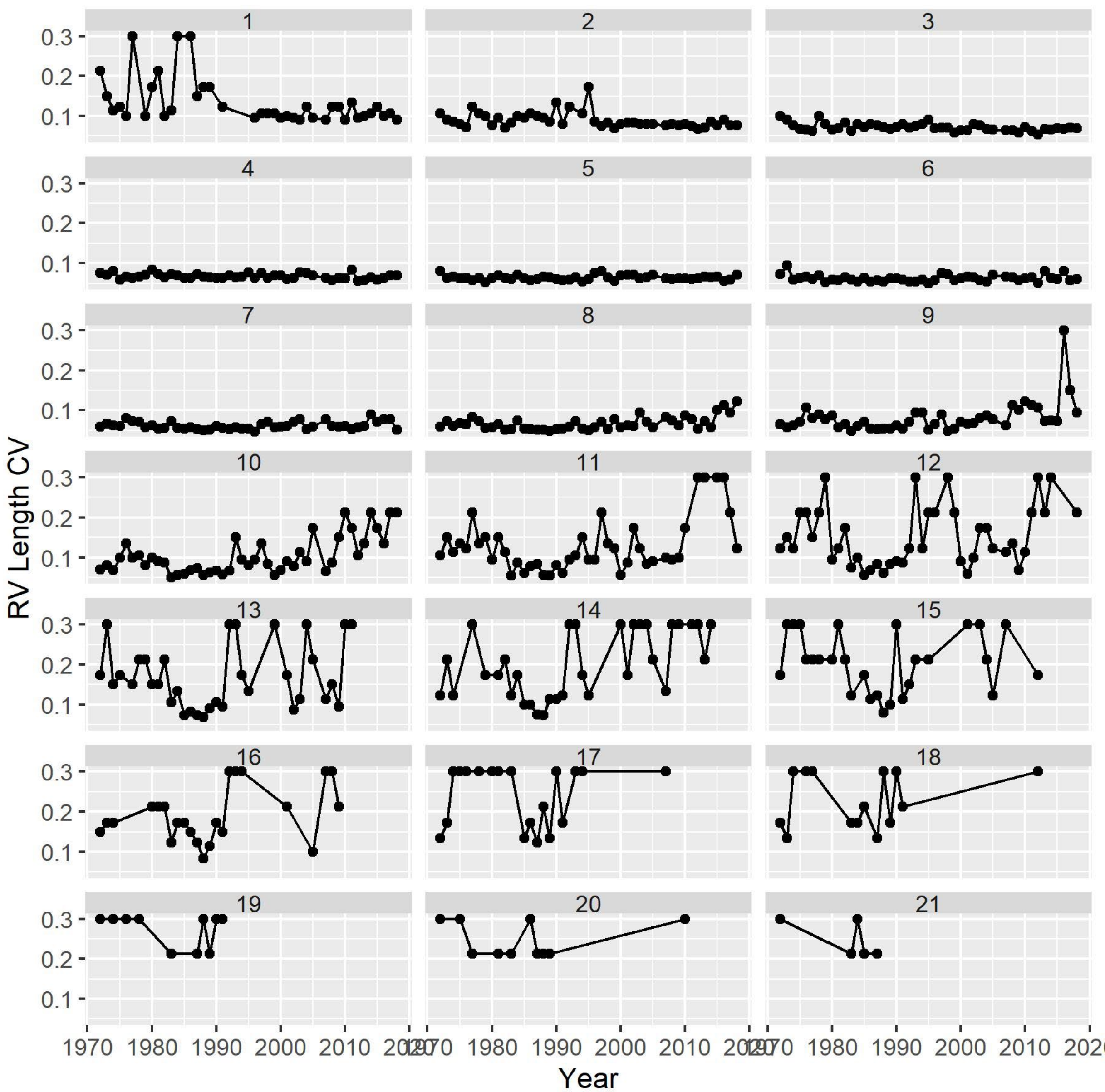

Figure 6. Coefficients of variation inferred from the age sample sizes for cod in the 3Ps DFO RV survey catches. Ages are listed at the top of each panel.

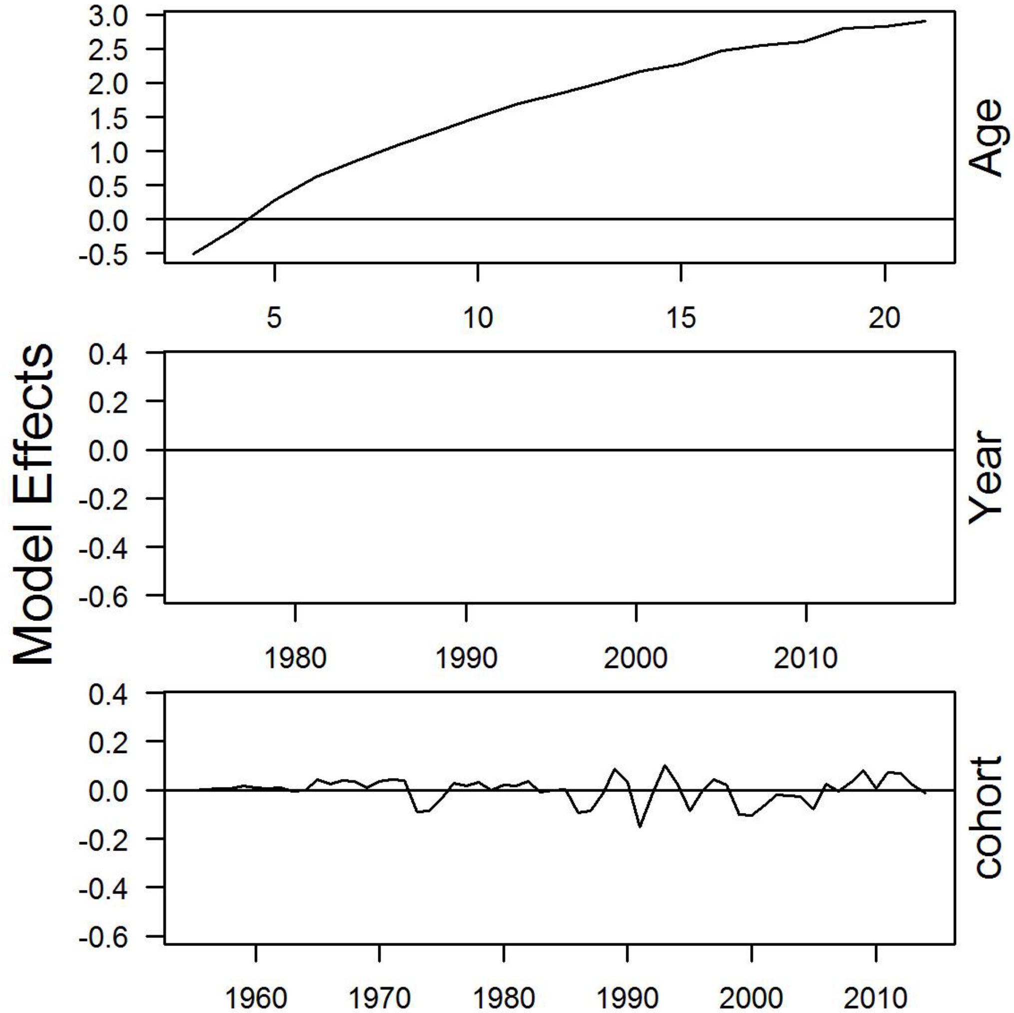

Figure 7. Age, year, and cohort effects from the fishery Wa model. The year effects are estimated to be essentially zero.

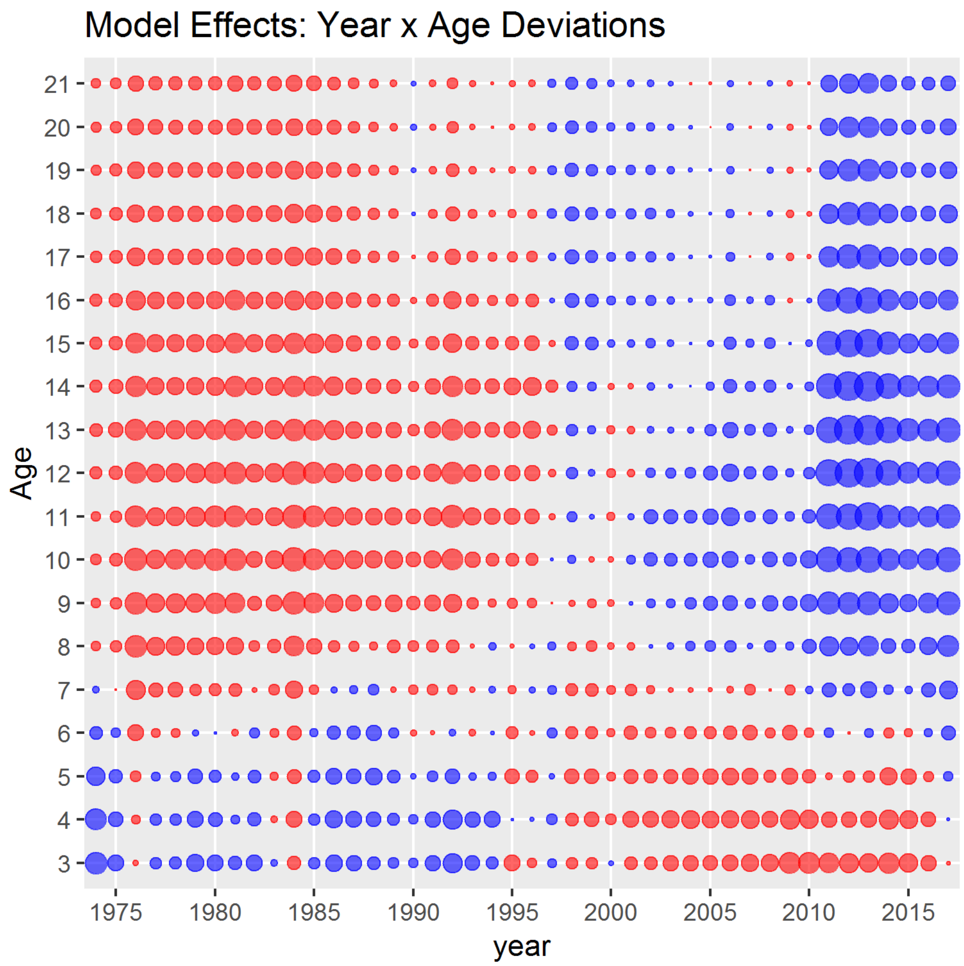

Figure 8. Age x year deviation effects from the fishery Wa model. Bubble area indicates the absolute value of the deviation. Red indicates a positive deviation and blue indicates a negative deviation.

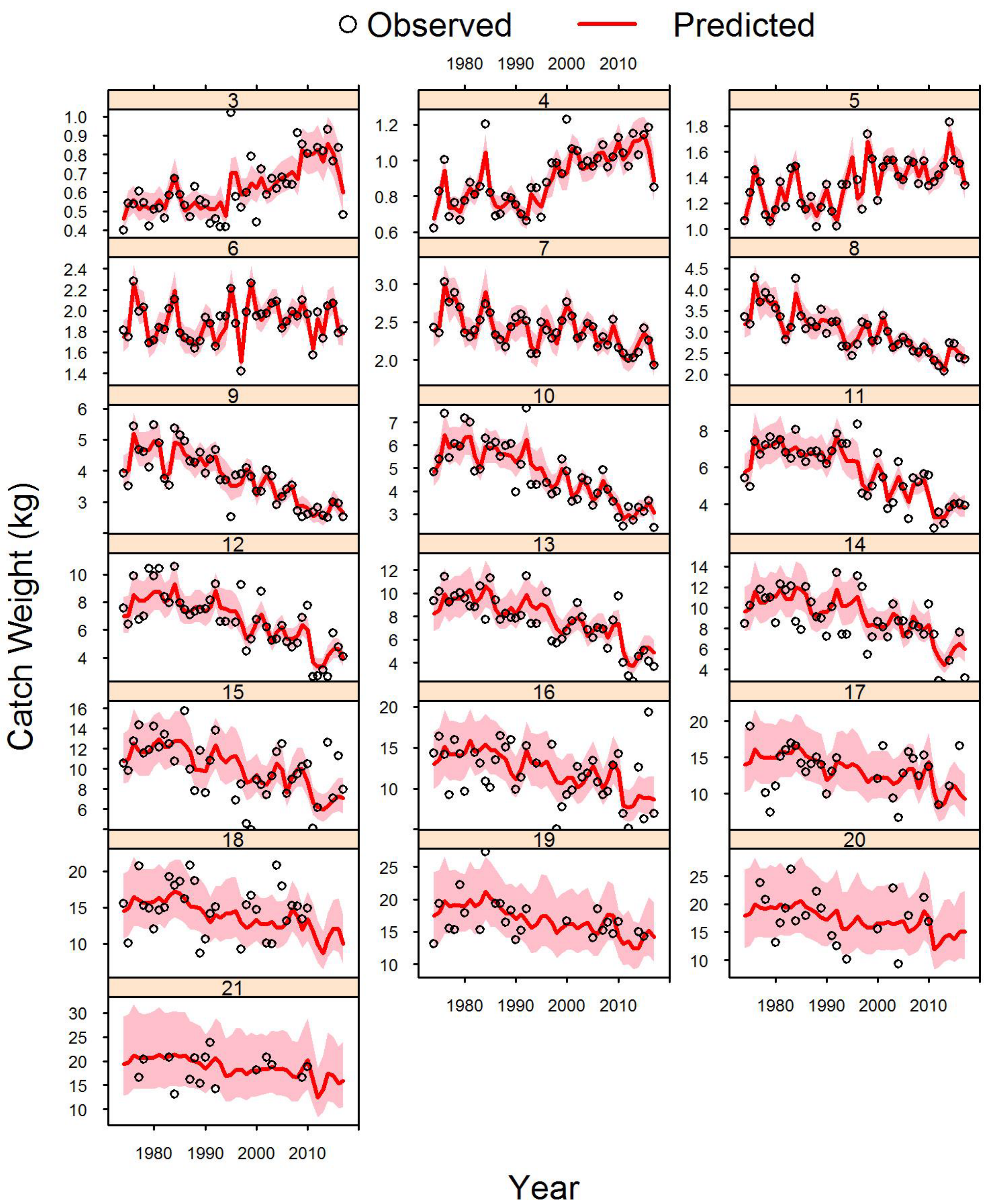

Figure 9. Observed (points) and model-predicted (lines) fishery Wa. Ages are listed at the top of each panel. Shaded regions indicate 95% confidence intervals.

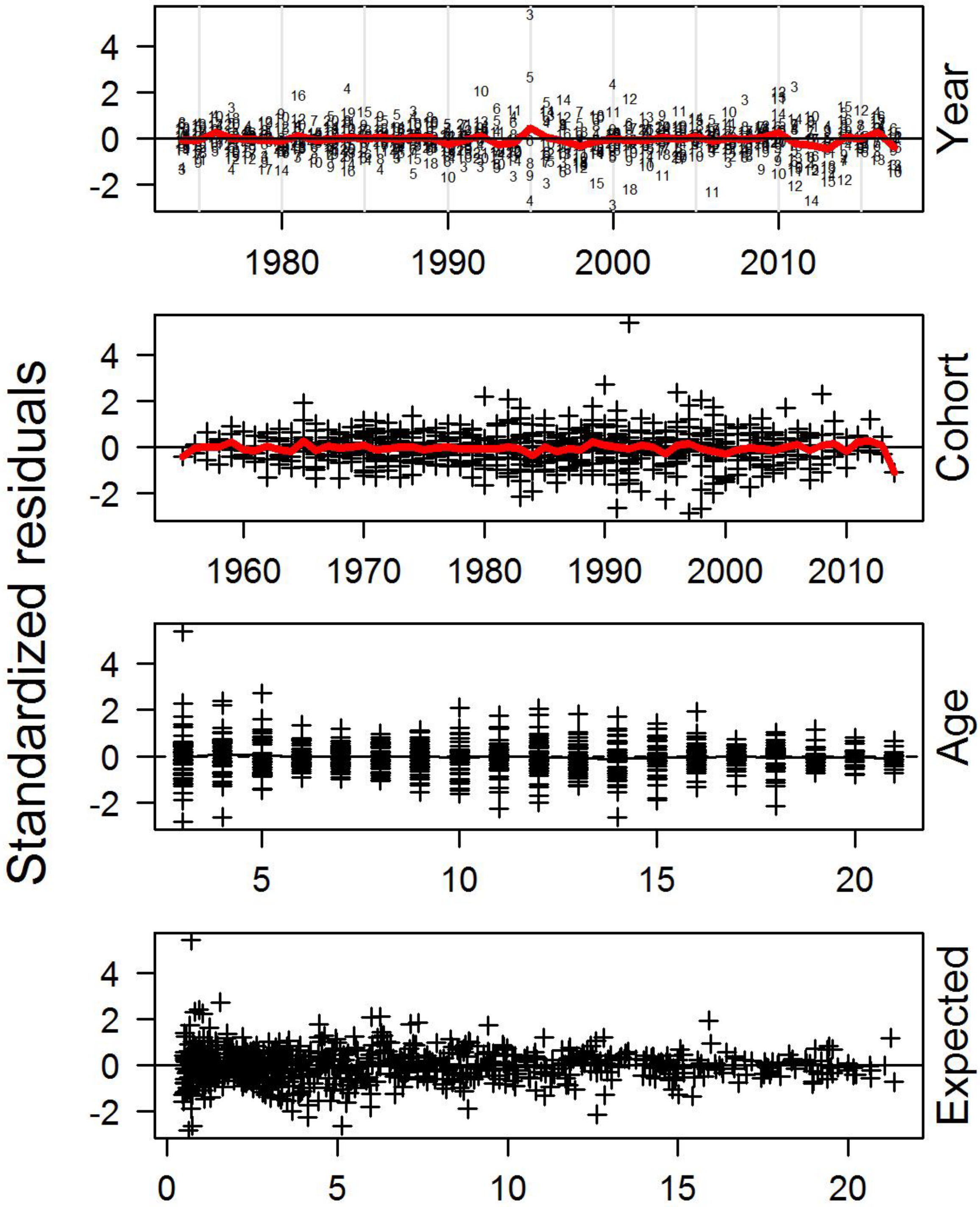

Figure 10. Standardized catch Wa residuals versus year (top panel), cohort (2nd panel), age (3rd panel) and model predicted value (bottom panel). Red lines indicate the average residual by year or cohort. The plotting symbols indicate age in the top panel.

Figure 11. Standardized catch Wa residuals versus age and year. Bubble area indicates the absolute value of the residual. Red indicates a positive deviation and blue indicates a negative deviation.

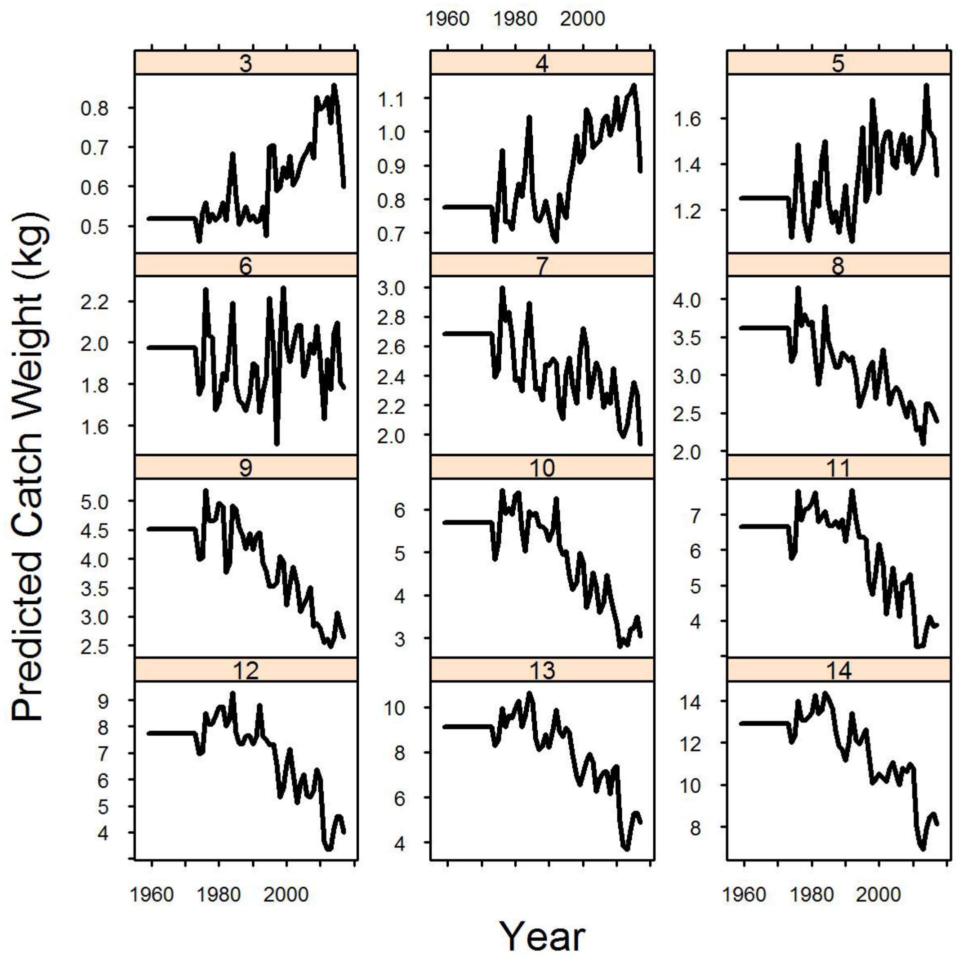

Figure 12. Model-predicted fishery Wa proposed for the stock assessment of 3Ps cod. Ages are listed at the top of each panel. Age 14 are plus group Wa (see text for method). Weights prior to 1974 were set at the 5-year average of the values for 1974–78.

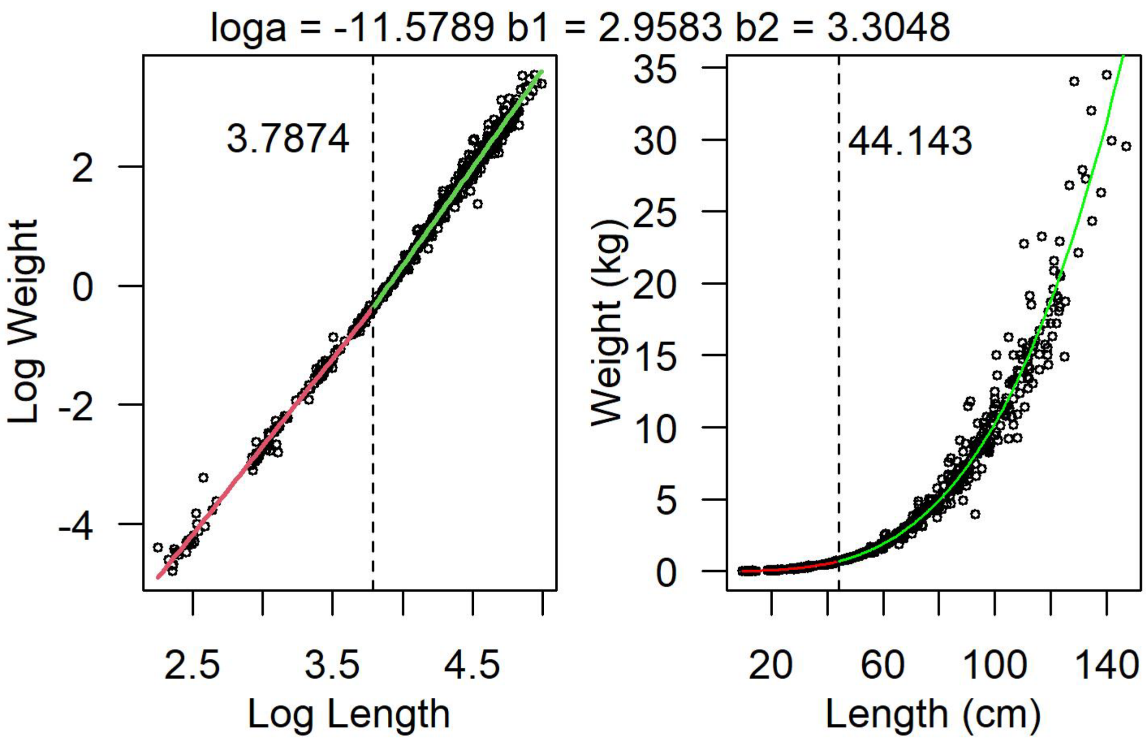

Figure 13. Left-hand panel: Log-weight versus log-length for cod in the 3Ps DFO RV survey catches. A segmented linear regression is shown as lines (red and green) with the estimated break-point indicated by the vertical dashed line. The intercept (loga), first segment slope (b1) and second segment slope (b2) are shown at the top of the panel. The break-point is indicated in the figure as log-length. Right-hand panel: Model fit to weight, with the break-point indicated by the vertical dashed-line.

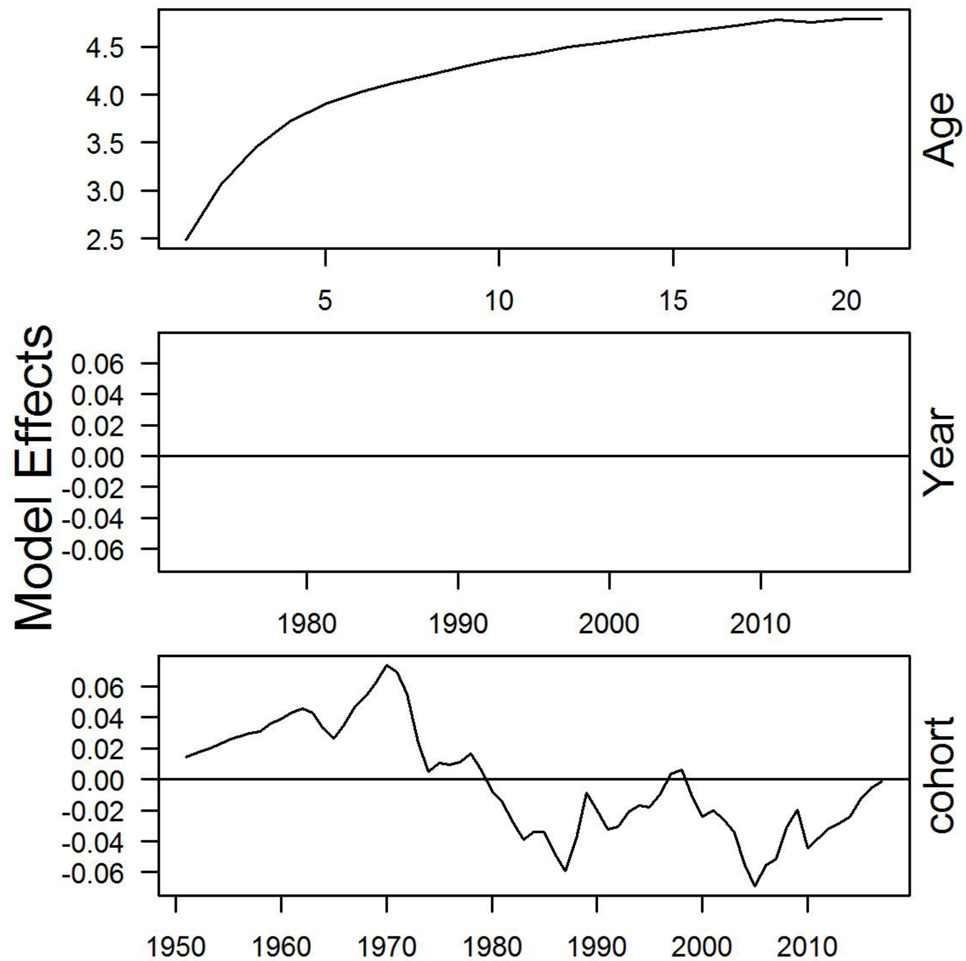

Figure 14. Age, year, and cohort effects from the 3Ps DFO RV cod La model. The year effects are estimated to be essentially zero.

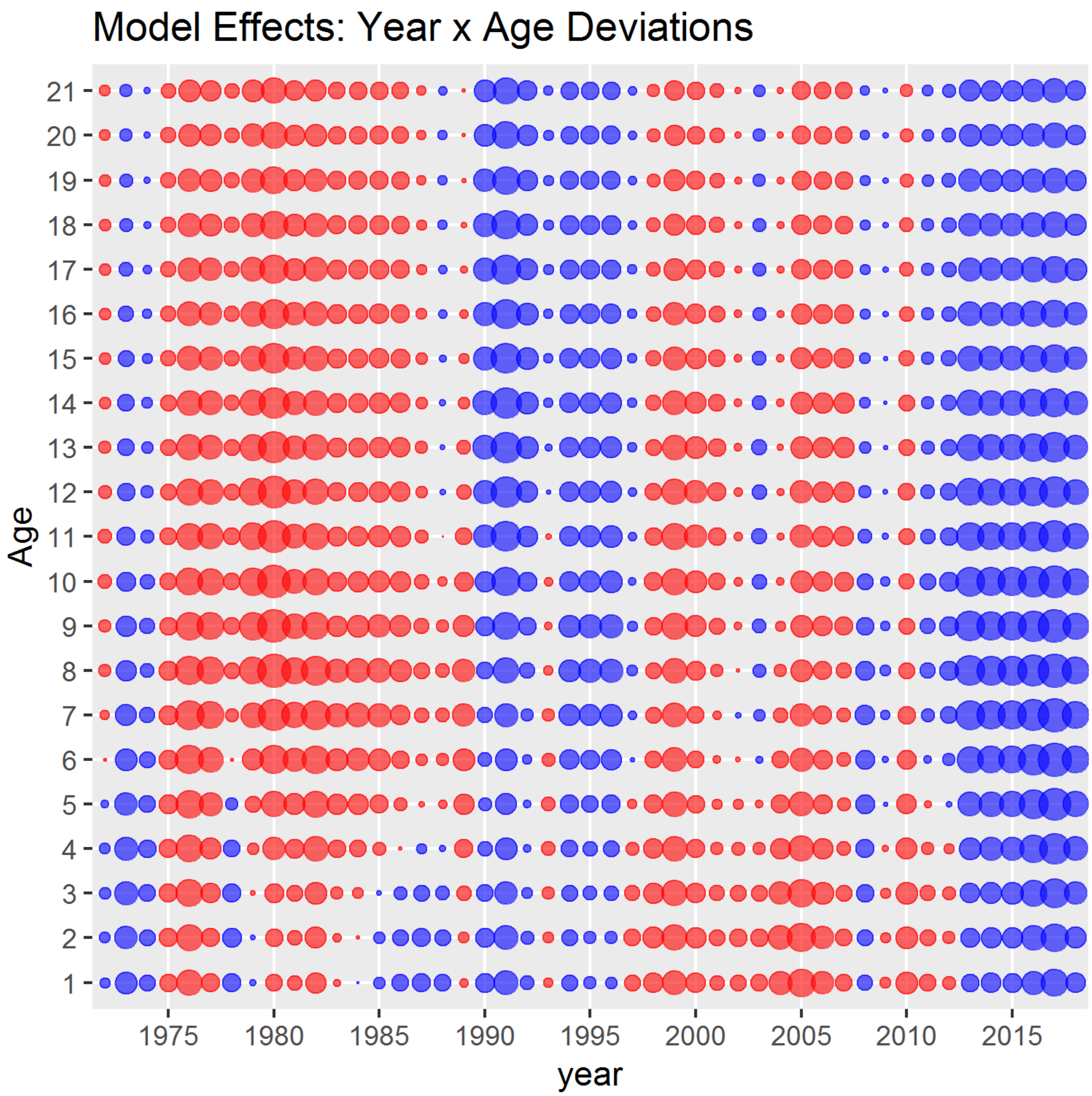

Figure 15. Age x year deviation effects from the 3Ps DFO RV cod La model. Bubble area indicates the absolute value of the deviation. Red indicates a positive deviation and blue indicates a negative deviation.

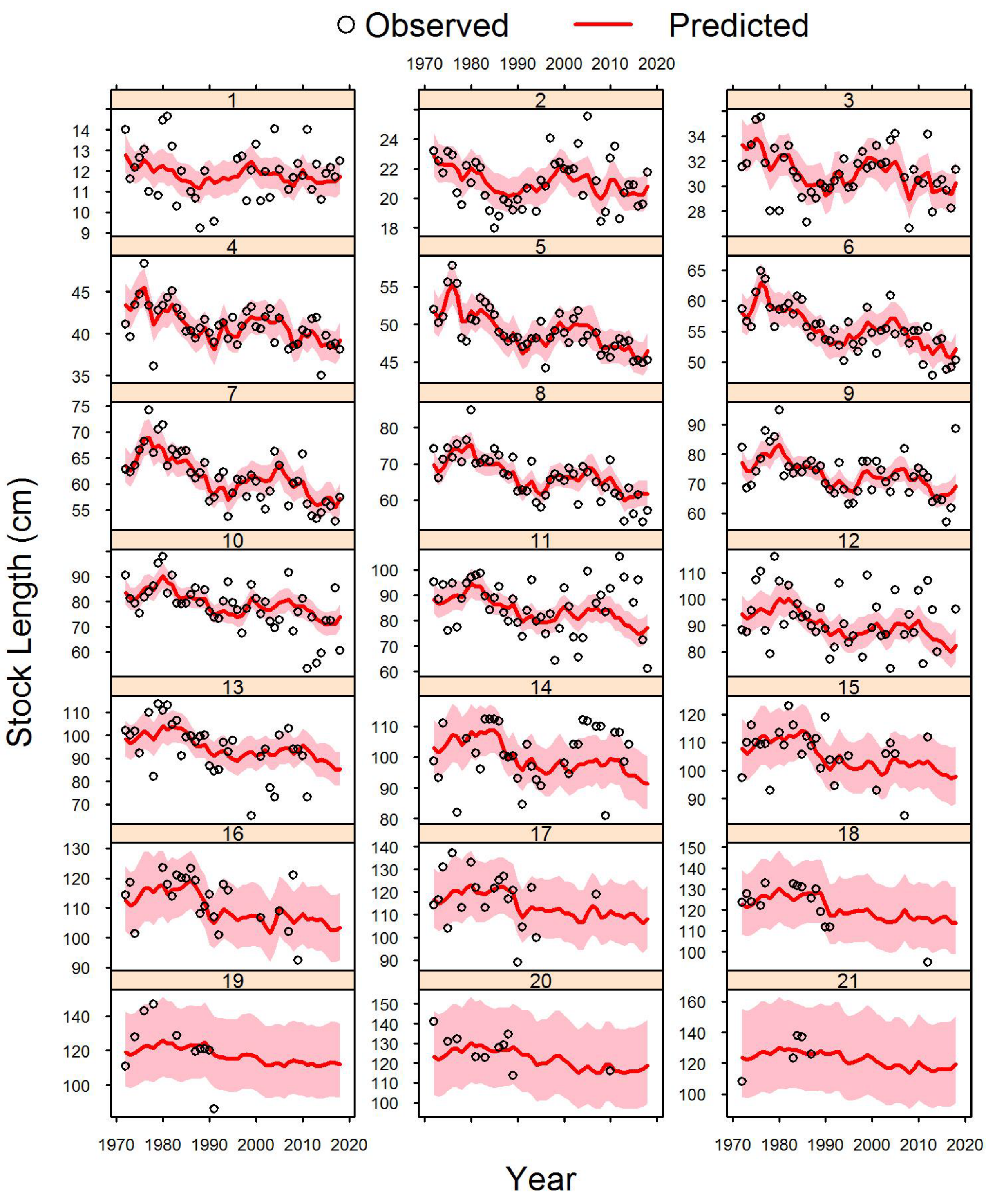

Figure 16a. Observed (points) and model-predicted (lines) 3Ps DFO RV cod La. Ages are listed at the top of each panel. Shaded regions indicate 95% confidence intervals.

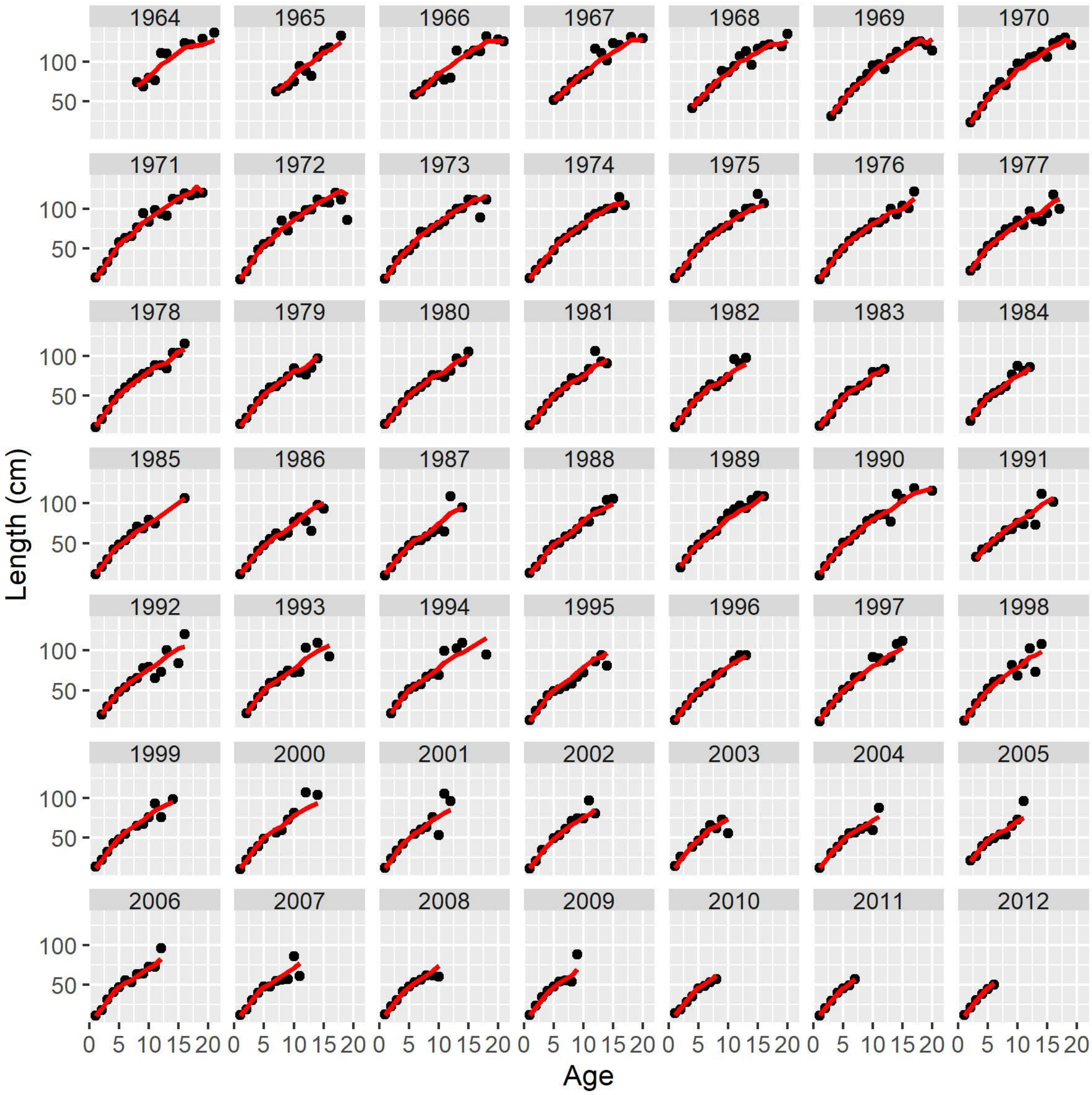

Figure 16b. Observed (points) and model-predicted (red lines) 3Ps DFO RV cod La. Cohorts are listed at the top of each panel.

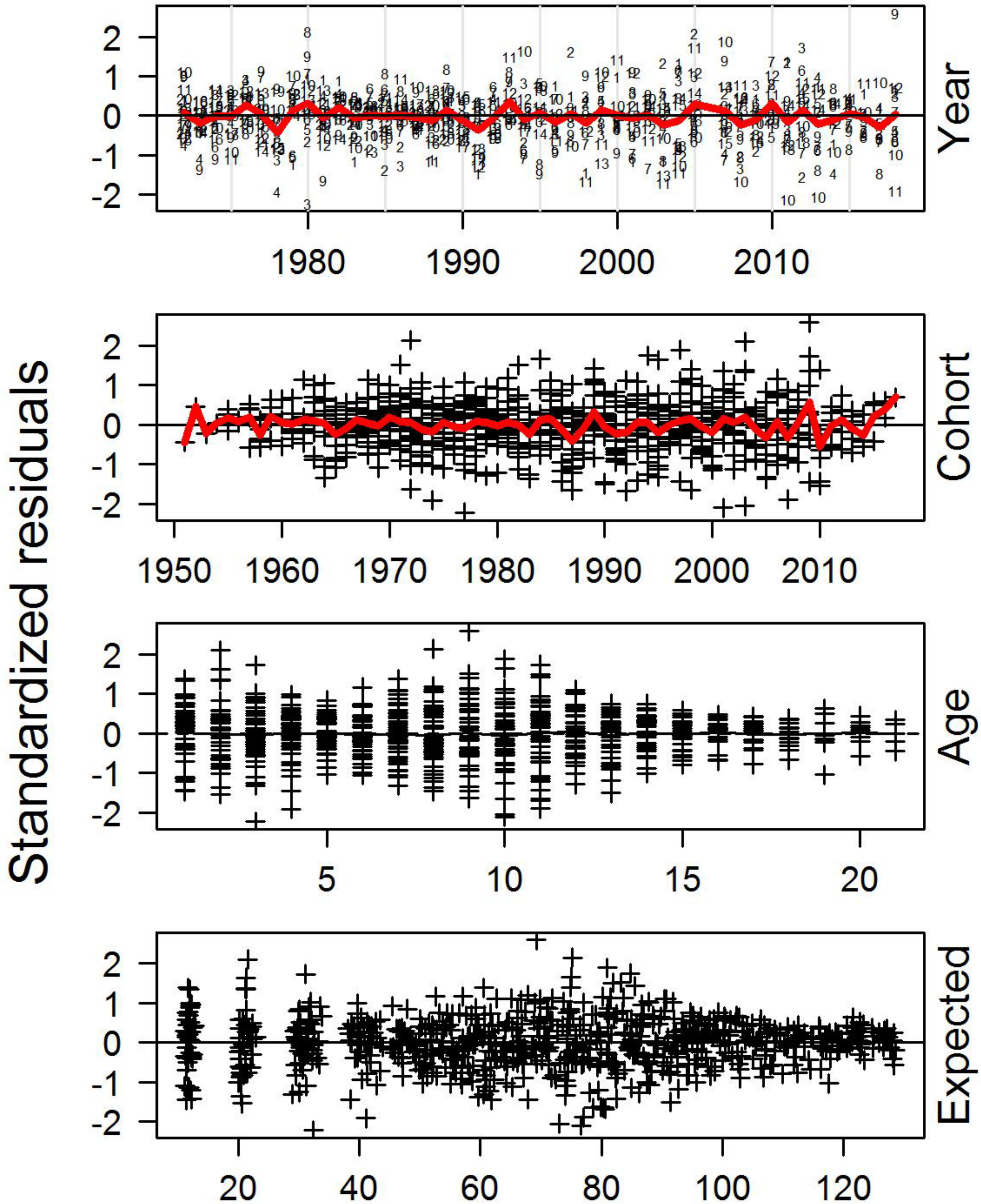

Figure 17. Standardized stock La residuals versus year (top panel), cohort (2nd panel), age (3rd panel) and model predicted value (bottom panel). Red lines indicate the average residual by year or cohort. The plotting symbols indicate age in the top panel.

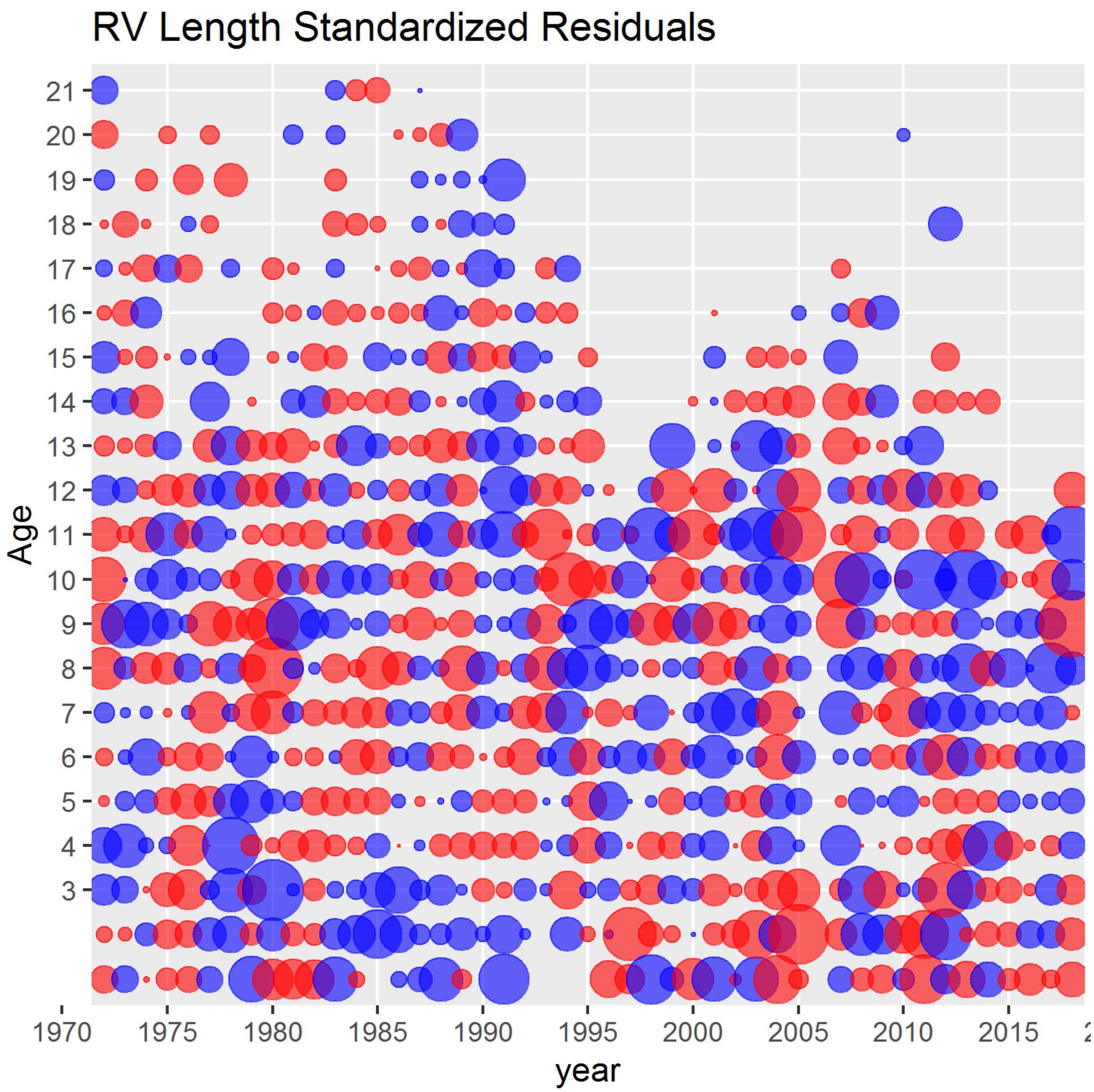

Figure 18. Standardized stock La residuals versus age and year. Bubble area indicates the absolute value of the residual. Red indicates a positive deviation and blue indicates a negative deviation.

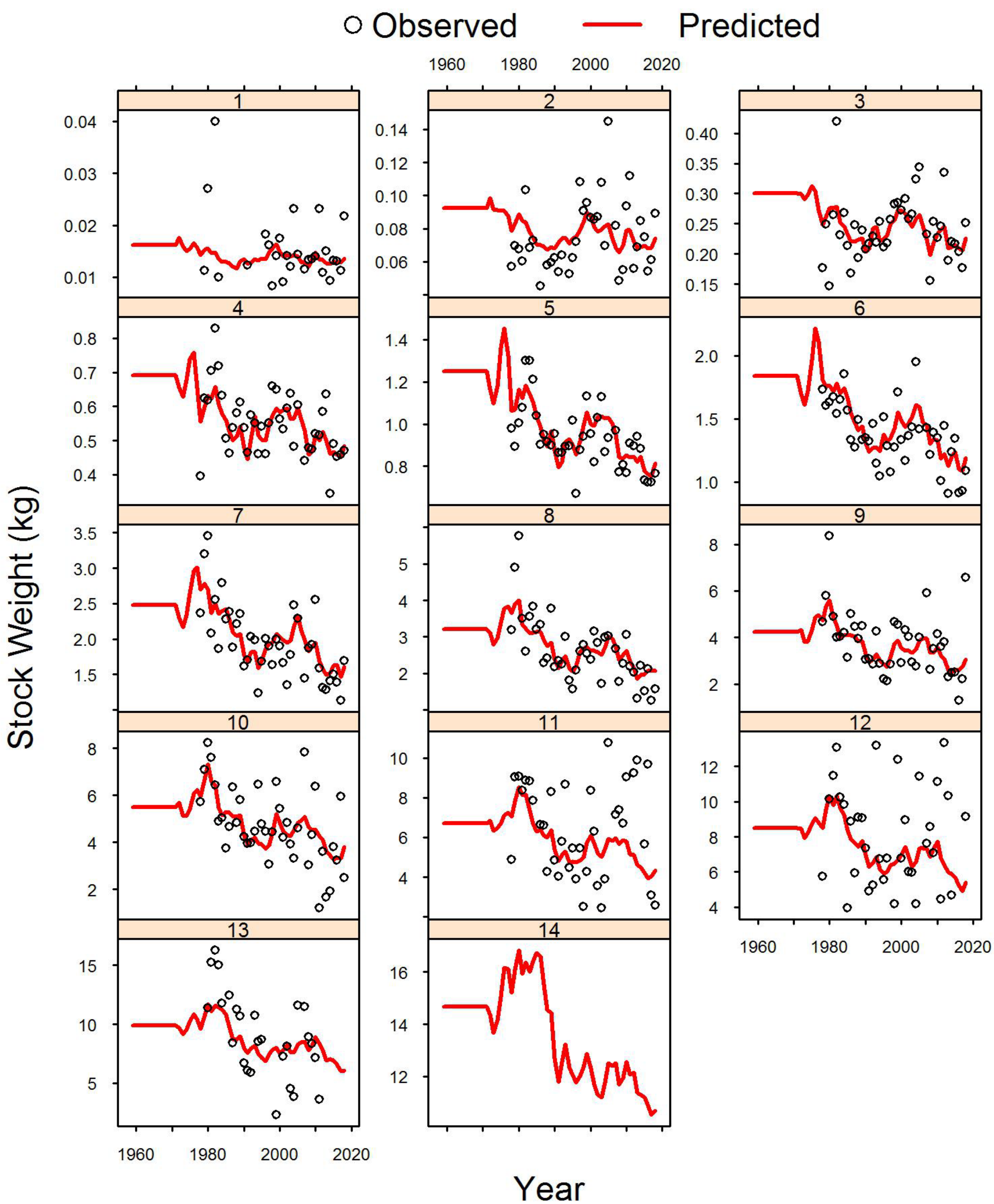

Figure 19. Model-predicted (lines) stock Wa proposed for the stock assessment of 3Ps cod. Ages are listed at the top of each panel. Age 14 are plus group Wa (see text for method). Points are survey Wa data but the model was not directly fit to these data. Stock weights prior to 1972 were set at the 5-year average of the values for 1972–76.

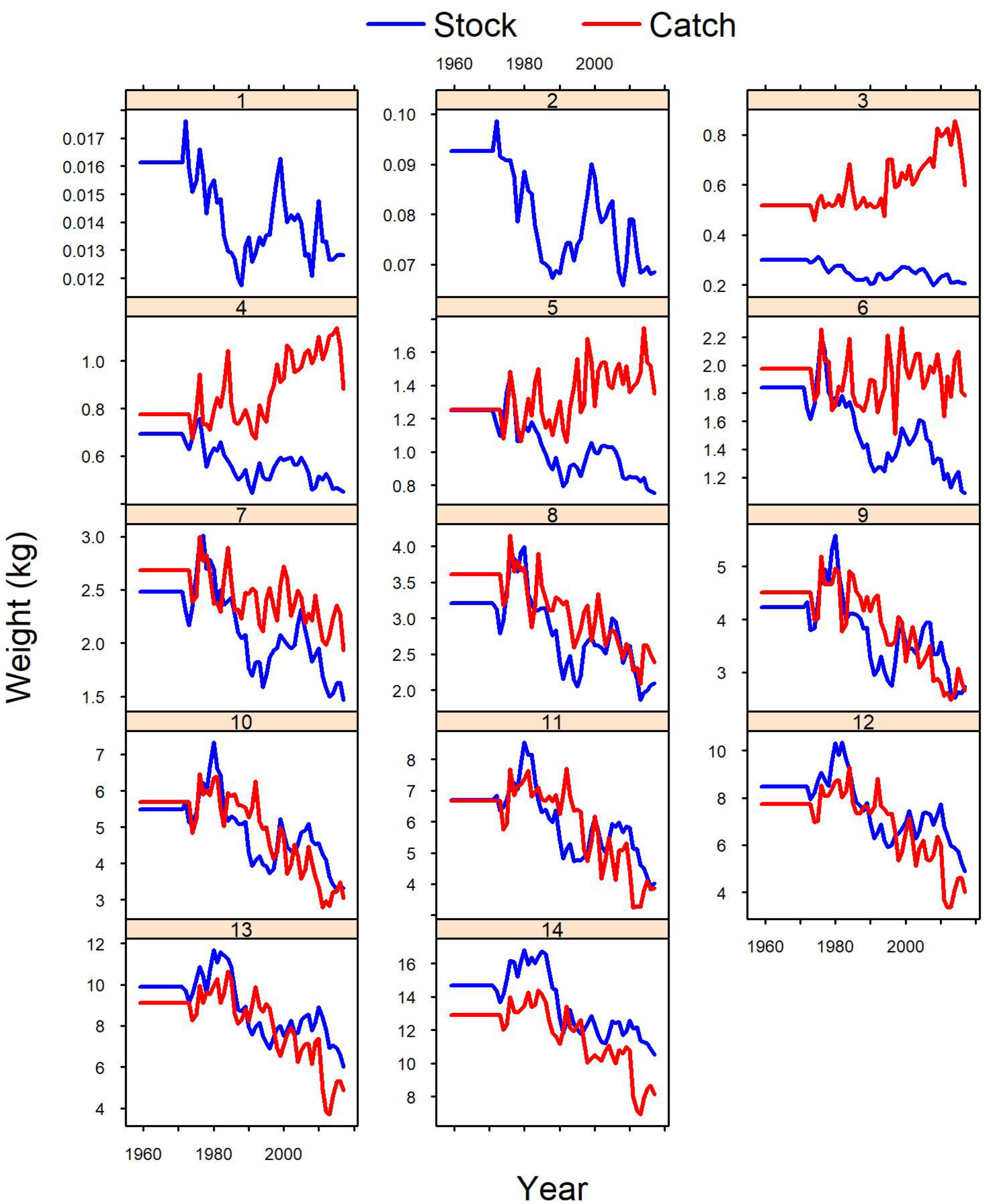

Figure 20. Comparison of model-predicted fishery (red lines) and stock (blue lines) Wa proposed for the stock assessment of 3Ps cod. Ages are listed at the top of each panel. Age 14 are plus group Wa (see text for method). Fisheries weights at ages 1 and 2 were not estimated because these ages are not caught, and the weights were fixed at zero. Fishery weights prior to 1974 were set at the 5-year average of the values for 1974–78. Stock weights prior to 1972 were set at the 5-year average of the values for 1972–76.

APPENDIX III – CODE

```
#include <TMB.hpp>
#include <iostream>

template<class Type>
  Type objective_function<Type>::operator() ()
{

  //input data;
    DATA_VECTOR(x);
    DATA_VECTOR(se);
    DATA_IVECTOR(ia);
    DATA_IVECTOR(iy);
    DATA_IVECTOR(ic);
    DATA_IVECTOR(iap);
    DATA_IVECTOR(iyp);
    DATA_IVECTOR(icp);

    int n = x.size();
    int np = icp.size();
    Type one = 1.0;
    Type zero = 0.0;

  // parameter effects;
    PARAMETER_VECTOR(age_eff);
    PARAMETER_VECTOR(year_eff);
    PARAMETER_VECTOR(cohort_eff);
    PARAMETER_VECTOR(log_std);
    PARAMETER_VECTOR(logit_ar);
    PARAMETER_ARRAY(dev);

    vector<Type> ar = exp(logit_ar)/(one + exp(logit_ar));
    vector<Type> std = exp(log_std);

    Type ar_year_eff = ar(0);
    Type ar_cohort_eff = ar(1);
    Type ar_dev_age = ar(2);
    Type ar_dev_year = ar(3);

    Type std_year_eff = std(0);
    Type std_cohort_eff = std(1);
    Type std_dev = std(2);

  //containers

    vector<Type> Ex(n);
    vector<Type> resid(n);
    vector<Type> std_resid(n);

    //initialize the negative log likelihood
```

```
  Type nll = zero;
  using namespace density;

  for(int i = 0;i < n;++i){
    Ex(i) = age_eff(ia(i)) + year_eff(iy(i)) + cohort_eff(ic(i)) + dev(iy(i),ia(i));
  }
  resid = x - Ex;
  std_resid = resid/se;

 //NEGATIVE LOGLIKELIHOODS
 //Index OBSERVATION MODEL
 nll -= dnorm(resid,zero,se,true).sum();

 //year effects
  nll += SCALE(AR1(ar_year_eff),std_year_eff)(year_eff);

 //cohort effects
  nll += SCALE(AR1(ar_cohort_eff),std_cohort_eff)(cohort_eff);

 // dev effects
  nll += SCALE(SEPARABLE(AR1(ar_dev_age),AR1(ar_dev_year)),std_dev)(dev);

  vector<Type> log_pred_wt(np);

  for(int i = 0;i < np;++i){
    log_pred_wt(i) = age_eff(iap(i)) + year_eff(iyp(i)) + cohort_eff(icp(i)) + dev(iyp(i),iap(i));
  }

        REPORT(age_eff);
        REPORT(year_eff);
        REPORT(cohort_eff);
        REPORT(dev);
        REPORT(Ex);
        REPORT(resid);
        REPORT(std_resid);
        REPORT(ar_year_eff);
        REPORT(ar_cohort_eff);
        REPORT(ar_dev_age);
        REPORT(ar_dev_year);
        REPORT(std_year_eff);
        REPORT(std_cohort_eff);
        REPORT(std_dev);

  ADREPORT(log_pred_wt);

return nll;
}
```

APPENDIX IV – INPUTS AND OUTPUTS

Catch Weight by Age														
-	**year**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1	1974	-	0.211	0.399	0.624	1.064	1.813	2.429	3.349	3.927	4.832	5.438	7.558	9.337
2	1975	-	-	0.543	0.827	1.281	1.750	2.355	3.182	3.509	5.381	4.971	6.417	10.185
3	1976	-	-	0.537	1.005	1.455	2.284	3.032	4.267	5.439	7.395	7.426	9.873	11.450
4	1977	-	-	0.606	0.684	1.367	1.992	2.765	3.703	4.684	5.452	6.701	6.741	9.225
5	1978	-	0.324	0.545	0.763	1.111	2.030	2.888	3.929	4.612	6.058	7.233	6.981	9.747
6	1979	-	0.303	0.422	0.668	1.056	1.692	2.694	3.776	4.125	5.942	7.650	10.423	10.032
7	1980	-	0.055	0.511	0.776	1.147	1.715	2.357	3.561	5.474	7.193	7.219	9.872	9.566
8	1981	-	0.248	0.516	0.877	1.366	1.839	2.303	3.359	4.893	6.991	7.520	10.414	8.871
9	1982	-	0.411	0.462	0.809	1.171	1.820	2.396	2.819	3.756	4.853	6.814	8.394	8.805
10	1983	-	0.296	0.583	0.853	1.472	2.019	2.525	3.099	3.523	4.952	6.486	7.968	10.613
11	1984	-	0.537	0.671	1.201	1.485	2.105	2.741	4.260	5.369	6.314	8.081	10.550	7.704
12	1985	-	-	0.588	0.821	1.200	1.783	2.626	3.373	5.149	5.941	6.740	7.940	11.320
13	1986	-	0.361	0.532	0.691	1.150	1.744	2.327	3.075	4.960	6.132	6.293	7.489	9.410
14	1987	-	0.330	0.472	0.701	1.251	1.707	2.270	3.248	4.299	5.523	6.867	7.072	7.730
15	1988	-	0.291	0.630	0.799	1.016	1.637	2.169	3.122	4.256	5.976	6.885	7.342	8.277
16	1989	-	0.311	0.559	0.790	1.166	1.709	2.441	3.531	4.580	6.081	6.529	7.448	7.889
17	1990	-	0.181	0.543	0.753	1.346	1.932	2.562	2.958	3.923	3.959	6.185	7.509	7.836
18	1991	-	0.287	0.435	0.700	1.135	1.877	2.608	3.234	4.382	5.150	6.894	8.143	8.065
19	1992	-	0.291	0.459	0.665	1.023	1.658	2.514	3.251	4.665	7.621	7.861	9.296	11.490
20	1993	-	-	0.417	0.848	1.344	1.945	2.080	2.652	3.701	4.286	7.307	6.585	7.378
21	1994	-	-	0.417	0.848	1.344	1.945	2.080	2.652	3.701	4.286	7.307	6.585	7.378
22	1995	-	-	1.020	0.681	1.966	2.210	2.499	2.434	2.513	-	-	-	-
23	1996	-	0.266	0.576	0.878	1.383	1.879	2.389	2.709	3.862	4.374	8.354	6.570	10.112
24	1997	-	0.292	0.519	0.984	1.153	1.417	2.285	3.233	3.903	3.863	4.585	9.272	5.847
25	1998	-	0.314	0.598	0.984	1.736	1.982	2.361	3.158	4.087	3.994	4.439	4.458	5.717
26	1999	-	0.128	0.789	0.924	1.543	2.263	2.520	2.784	3.822	5.389	4.985	5.333	6.041

Catch Weight by Age														
-	**year**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
27	2000	-	0.192	0.442	1.230	1.219	1.949	2.763	2.808	3.337	4.858	6.799	6.719	6.717
28	2001	-	0.333	0.722	1.063	1.478	1.964	2.579	3.379	3.347	3.538	5.472	8.750	7.591
29	2002	-	0.348	0.586	1.053	1.531	1.972	2.289	3.013	4.023	3.627	3.751	6.198	9.153
30	2003	-	0.361	0.673	0.971	1.531	2.067	2.316	2.621	3.836	4.581	4.066	5.251	7.968
31	2004	-	0.282	0.619	0.996	1.409	2.091	2.479	2.709	2.901	4.450	6.298	5.331	6.880
32	2005	-	0.373	0.681	0.967	1.381	1.832	2.438	2.870	3.165	3.370	4.944	6.296	6.136
33	2006	0.248	0.324	0.643	1.012	1.530	1.898	2.175	2.732	3.405	3.890	3.213	5.147	7.014
34	2007	-	0.299	0.642	1.085	1.517	1.991	2.300	2.556	3.535	4.912	5.425	4.765	6.897
35	2008	-	0.371	0.912	0.961	1.349	1.949	2.202	2.522	2.717	4.073	5.214	5.041	5.257
36	2009	1.457	4.406	0.853	1.017	1.528	2.103	2.532	2.648	2.518	3.543	5.643	6.885	7.686
37	2010	-	0.341	0.805	1.128	1.334	1.966	2.161	2.523	2.605	2.850	5.562	7.751	9.753
38	2011	0.229	0.593	1.071	1.041	1.364	1.572	2.091	2.329	2.678	2.456	2.684	2.640	4.021
39	2012	0.055	0.176	0.836	0.965	1.418	1.982	2.019	2.206	2.820	3.305	3.559	2.665	2.849
40	2013	-	0.212	0.819	1.149	1.487	1.732	2.034	2.067	2.560	2.733	2.926	3.104	2.364
41	2014	-	0.288	0.930	1.030	1.832	2.046	2.097	2.731	2.490	3.281	3.826	2.644	4.532
42	2015	-	0.086	0.766	1.144	1.532	2.067	2.416	2.727	2.991	3.116	3.997	5.790	5.072
43	2016	-	0.128	0.837	1.184	1.506	1.787	2.261	2.385	2.958	3.575	4.038	4.749	4.140
44	2017	-	0.248	0.481	0.852	1.338	1.816	1.932	2.361	2.528	2.396	3.937	4.070	3.654

Catch Weight by Age												
-	**year**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
1	1974	8.466	10.543	14.280	-	15.512	13.097	-	-	15.289	12.044	-
2	1975	10.185	9.800	16.411	19.308	10.112	19.308	-	-	-	-	-
3	1976	16.628	12.723	14.125	-	-	-	-	-	-	-	-
4	1977	11.753	14.379	9.230	-	20.671	15.536	23.854	16.628	-	-	-
5	1978	10.954	11.579	15.928	10.112	15.247	15.273	20.807	20.317	-	-	-
6	1979	10.987	11.867	14.211	7.368	14.837	22.266	-	-	-	-	17.934
7	1980	8.527	14.204	9.645	11.049	12.044	17.934	13.097	-	-	22.266	-

Catch Weight by Age												
-	year	14	15	16	17	18	19	20	21	22	23	24
8	1981	12.302	12.128	25.516	15.089	14.571	-	16.628	-	-	-	-
9	1982	11.688	13.398	14.400	16.063	15.017	-	19.308	-	-	-	-
10	1983	12.076	12.491	13.046	16.961	19.236	15.295	26.194	20.828	11.049	-	20.915
11	1984	8.682	10.728	10.846	16.628	17.986	27.338	16.959	13.097	-	-	-
12	1985	7.876	18.065	10.141	14.211	18.619	-	-	-	-	-	-
13	1986	12.003	15.740	13.460	12.999	16.133	19.308	17.934	-	14.211	-	-
14	1987	10.514	9.981	16.453	14.109	20.751	19.366	-	16.176	-	23.854	20.751
15	1988	9.126	7.799	15.036	15.002	18.692	16.434	22.258	20.671	14.211	17.934	19.277
16	1989	8.980	11.828	15.981	14.016	8.660	18.314	19.308	15.387	-	17.934	-
17	1990	7.231	7.627	9.855	9.910	10.679	13.733	-	20.751	27.255	-	19.308
18	1991	10.071	10.807	11.321	13.048	14.112	15.223	14.308	23.854	13.097	-	-
19	1992	13.430	13.838	15.249	14.962	15.096	18.471	12.514	14.211	-	-	-
20	1993	7.435	-	-	-	-	-	-	-	-	-	-
21	1994	7.435	-	13.097	-	-	-	10.112	-	-	-	-
22	1996	13.097	6.898	-	-	-	-	-	-	-	-	-
23	1997	12.044	8.512	15.387	-	9.230	-	-	-	-	-	-
24	1998	5.459	4.520	5.001	-	15.362	-	-	-	-	-	-
25	1999	7.166	3.922	7.777	-	16.628	-	-	-	-	8.401	25.516
26	2000	8.679	8.967	9.217	12.062	14.677	16.628	15.535	18.072	16.082	22.266	-
27	2001	8.118	8.403	9.793	16.628	3.955	-	-	-	-	-	-
28	2002	7.133	7.382	12.688	-	10.112	-	-	20.751	-	-	-
29	2003	10.317	9.288	11.367	9.353	9.947	-	22.813	19.206	-	10.112	20.751
30	2004	8.703	11.663	11.862	6.695	20.751	-	9.230	-	-	-	-
31	2005	8.697	12.515	13.373	12.788	17.934	14.035	-	-	19.308	25.516	-
32	2006	7.387	7.562	10.813	15.766	13.097	18.495	17.934	-	14.211	-	-
33	2007	8.299	8.981	9.254	14.860	15.225	15.220	-	-	-	-	-
34	2008	8.153	9.501	9.628	12.379	15.129	16.465	-	-	-	-	-
35	2009	7.414	10.235	12.839	15.285	13.401	14.721	21.127	16.628	-	-	-
36	2010	10.329	10.513	14.200	13.753	14.875	16.515	16.841	18.764	-	-	-

Catch Weight by Age												
-	year	14	15	16	17	18	19	20	21	22	23	24
37	2011	7.386	4.045	6.898	-	-	-	-	-	-	-	-
38	2012	2.897	6.164	5.091	8.401	-	-	-	-	-	-	-
39	2013	2.583	2.006	-	-	3.955	-	-	-	-	-	-
40	2014	4.873	12.601	12.602	11.049	-	14.938	-	-	-	-	-
41	2015	-	7.107	6.220	-	-	14.211	-	-	-	-	-
42	2016	7.625	11.282	19.308	16.628	-	-	-	-	15.387	-	-
43	2017	3.158	7.968	6.898	-	-	-	-	-	-	-	-

Catch CV by Age														
-	year	1	2	3	4	5	6	7	8	9	10	11	12	13
1	1974	-	0.65	0.08	0.06	0.06	0.06	0.07	0.07	0.08	0.10	0.15	0.19	0.22
2	1975	-	-	0.11	0.06	0.10	0.06	0.05	0.14	0.18	0.14	0.26	0.38	0.29
3	1976	-	-	0.09	0.05	0.03	0.05	0.05	0.07	0.12	0.15	0.20	0.26	0.46
4	1977	-	-	0.11	0.04	0.05	0.07	0.15	0.14	0.12	0.17	0.23	0.24	0.33
5	1978	-	0.70	0.15	0.06	0.05	0.05	0.07	0.10	0.13	0.10	0.14	0.16	0.19
6	1979	-	0.49	0.39	0.11	0.03	0.06	0.07	0.08	0.16	0.31	0.26	0.37	0.41
7	1980	-	0.01	0.11	0.09	0.06	0.04	0.08	0.08	0.08	0.14	0.14	0.25	0.28
8	1981	-	1.31	0.07	0.05	0.08	0.05	0.04	0.06	0.11	0.17	0.26	0.21	0.49
9	1982	-	0.38	0.22	0.03	0.04	0.07	0.05	0.04	0.12	0.14	0.17	0.23	0.24
10	1983	-	0.24	0.04	0.05	0.02	0.06	0.09	0.08	0.08	0.11	0.13	0.25	0.17
11	1984	-	0.99	0.15	0.06	0.05	0.06	0.14	0.14	0.15	0.16	0.23	0.36	0.87
12	1985	-	-	0.10	0.05	0.03	0.04	0.03	0.06	0.09	0.10	0.13	0.20	0.27
13	1986	-	0.44	0.15	0.05	0.05	0.05	0.08	0.07	0.08	0.13	0.10	0.11	0.14
14	1987	-	0.51	0.11	0.06	0.04	0.05	0.05	0.10	0.07	0.11	0.11	0.10	0.12
15	1988	-	0.25	0.08	0.04	0.06	0.05	0.07	0.08	0.11	0.09	0.13	0.20	0.23
16	1989	-	0.82	0.18	0.05	0.06	0.10	0.05	0.07	0.10	0.13	0.16	0.22	0.35
17	1990	-	0.88	0.08	0.03	0.04	0.08	0.11	0.13	0.13	0.23	0.17	0.20	0.18
18	1991	-	0.33	0.13	0.04	0.05	0.04	0.06	0.09	0.07	0.07	0.10	0.13	0.11

Catch CV by Age														
-	**year**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
19	1992	-	0.42	0.05	0.05	0.03	0.03	0.05	0.08	0.09	0.07	0.08	0.10	0.13
20	1993	-	-	0.31	0.17	0.10	0.10	0.11	0.14	0.18	0.23	0.26	0.37	0.49
21	1994	-	-	0.02	0.13	0.05	0.11	0.10	0.15	0.19	0.37	0.08	0.36	0.46
22	1995	-	-	0.00	0.00	0.12	0.05	0.11	0.14	0.34	-	-	-	-
23	1996	-	0.13	0.07	0.03	0.09	0.07	0.05	0.12	0.13	0.18	0.31	0.18	0.01
24	1997	-	0.23	0.12	0.22	0.10	0.17	0.11	0.08	0.16	0.23	0.23	0.53	0.72
25	1998	-	0.40	0.07	0.04	0.04	0.03	0.05	0.03	0.03	0.07	0.09	0.11	0.15
26	1999	-	0.01	0.30	0.06	0.05	0.04	0.03	0.05	0.05	0.04	0.09	0.11	0.16
27	2000	-	0.72	0.10	0.17	0.06	0.07	0.06	0.07	0.10	0.04	0.02	0.08	0.12
28	2001	-	0.22	0.07	0.03	0.04	0.03	0.03	0.04	0.04	0.05	0.07	0.04	0.12
29	2002	-	0.76	0.05	0.03	0.02	0.02	0.02	0.03	0.03	0.04	0.08	0.08	0.06
30	2003	-	0.44	0.12	0.04	0.03	0.02	0.03	0.03	0.04	0.05	0.07	0.09	0.09
31	2004	-	0.32	0.06	0.06	0.03	0.02	0.02	0.04	0.06	0.07	0.08	0.09	0.12
32	2005	-	0.45	0.11	0.04	0.03	0.02	0.02	0.02	0.03	0.05	0.07	0.12	0.13
33	2006	1.29	0.29	0.11	0.04	0.02	0.02	0.03	0.02	0.03	0.04	0.08	0.10	0.12
34	2007	-	0.28	0.06	0.04	0.03	0.03	0.03	0.04	0.03	0.04	0.06	0.12	0.12
35	2008	-	0.47	0.22	0.07	0.06	0.03	0.04	0.04	0.05	0.05	0.05	0.12	0.19
36	2009	0.95	0.68	0.09	0.07	0.05	0.06	0.06	0.06	0.12	0.08	0.09	0.08	0.10
37	2010	-	0.14	0.19	0.06	0.05	0.03	0.03	0.05	0.06	0.10	0.11	0.06	0.06
38	2011	0.62	0.35	0.11	0.09	0.03	0.03	0.03	0.04	0.06	0.10	0.14	0.14	0.24
39	2012	0.02	0.17	0.20	0.08	0.06	0.03	0.04	0.05	0.08	0.09	0.15	0.16	0.22
40	2013	-	0.18	0.22	0.07	0.05	0.06	0.05	0.05	0.08	0.15	0.26	0.28	0.46
41	2014	-	0.09	0.18	0.11	0.03	0.04	0.07	0.05	0.08	0.12	0.15	0.33	0.40
42	2015	-	0.40	0.31	0.04	0.05	0.02	0.03	0.06	0.05	0.10	0.14	0.17	0.27
43	2016	-	0.01	0.55	0.11	0.03	0.05	0.04	0.06	0.08	0.07	0.13	0.15	0.33
44	2017	-	0.56	0.26	0.20	0.09	0.03	0.07	0.07	0.12	0.22	0.18	0.26	0.28

Catch CV by Age												
-	**year**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
1	1974	0.29	0.12	0.37	-	0.49	1.05	-	-	0.77	0.97	-
2	1975	0.62	0.36	0.21	1.31	0.88	1.31	-	-	-	-	-
3	1976	0.87	0.40	0.52	-	-	-	-	-	-	-	-
4	1977	0.51	1.02	1.31	-	0.05	0.14	0.02	1.18	-	-	-
5	1978	0.22	0.26	0.29	0.72	0.44	0.70	0.34	0.39	-	-	-
6	1979	0.38	0.72	1.03	0.62	0.63	0.03	-	-	-	-	0.94
7	1980	0.12	0.22	0.89	0.65	0.56	0.02	1.35	-	-	1.35	-
8	1981	0.17	0.05	0.02	0.28	0.11	-	0.86	-	-	-	-
9	1982	0.33	0.29	0.42	0.31	0.94	-	0.02	-	-	-	-
10	1983	0.14	0.18	0.17	0.30	0.29	0.37	0.14	0.58	1.12	-	0.57
11	1984	0.33	0.98	0.05	0.11	0.02	0.02	0.24	0.76	-	-	-
12	1985	0.66	0.21	0.69	0.80	0.37	-	-	-	-	-	-
13	1986	0.25	0.20	0.35	0.44	0.22	0.03	0.96	-	0.80	-	-
14	1987	0.11	0.17	0.31	0.21	0.86	0.20	-	0.47	-	0.99	1.05
15	1988	0.22	0.21	0.34	0.47	0.12	0.16	1.01	0.50	1.08	1.08	0.03
16	1989	0.22	0.18	0.33	0.64	0.52	0.14	1.18	0.76	-	0.02	-
17	1990	0.44	0.41	0.33	0.38	0.65	0.60	-	0.88	0.01	-	0.01
18	1991	0.14	0.19	0.22	0.22	0.27	0.37	0.35	0.03	0.62	-	-
19	1992	0.13	0.16	0.13	0.21	0.23	0.33	0.43	0.75	-	-	-
20	1993	0.66	-	-	-	-	-	-	-	-	-	-
21	1994	0.42	-	0.03	-	-	-	0.96	-	-	-	-
22	1996	0.01	0.66	-	-	-	-	-	-	-	-	-
23	1997	0.01	1.25	1.49	-	0.00	-	-	-	-	-	-
24	1998	0.51	0.94	0.92	-	0.84	-	-	-	-	-	-
25	1999	0.25	0.48	0.71	-	0.03	-	-	-	-	1.03	0.01
26	2000	0.20	0.21	0.38	0.48	0.14	0.80	0.31	0.54	0.01	0.01	-
27	2001	0.16	0.20	0.30	0.76	0.57	-	-	-	-	-	-
28	2002	0.16	0.24	0.58	-	0.91	-	-	0.01	-	-	-
29	2003	0.05	0.16	0.44	0.67	0.33	-	0.59	0.45	-	0.84	0.01

Catch CV by Age												
-	**year**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
30	2004	0.21	0.13	0.30	0.85	3.82	-	0.95	-	-	-	-
31	2005	0.13	0.18	0.20	0.28	0.74	0.59	-	-	0.01	0.02	-
32	2006	0.13	0.51	0.21	0.16	0.01	0.75	0.99	-	0.01	-	-
33	2007	0.12	0.20	0.24	0.15	0.20	0.44	-	-	-	-	-
34	2008	0.23	0.18	0.29	0.25	0.27	0.72	-	-	-	-	-
35	2009	0.24	0.26	0.25	0.27	0.15	0.20	0.45	0.65	-	-	-
36	2010	0.12	0.17	0.35	0.31	0.26	0.40	0.34	0.47	-	-	-
37	2011	0.19	0.43	0.49	-	-	-	-	-	-	-	-
38	2012	0.16	0.23	0.66	1.31	-	-	-	-	-	-	-
39	2013	0.42	0.82	-	-	0.89	-	-	-	-	-	-
40	2014	0.36	0.61	0.30	0.03	-	0.55	-	-	-	-	-
41	2015	-	0.03	0.83	-	-	0.01	-	-	-	-	-
42	2016	0.26	0.63	1.10	0.92	-	-	-	-	0.01	-	-
43	2017	0.73	0.40	0.78	-	-	-	-	-	-	-	-

RV Mean Length by Age												
-	**year**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1	1972	13.991	23.223	31.541	41.113	51.980	58.639	62.774	74.227	82.267	90.604	95.037
2	1973	11.625	22.519	31.787	39.636	50.188	56.558	62.288	66.099	68.504	81.072	88.457
3	1974	12.154	21.725	33.326	43.484	51.002	55.705	63.631	71.131	69.394	79.371	94.045
4	1975	12.660	23.141	35.352	44.710	55.595	61.322	66.482	74.397	74.162	75.227	76.173
5	1976	13.026	22.932	35.558	48.393	57.857	64.824	68.171	71.807	78.398	81.729	94.697
6	1977	11.000	20.359	31.888	43.394	55.483	63.575	74.205	75.399	87.982	83.769	77.321
7	1978	-	19.558	28.005	36.102	48.215	58.913	66.019	70.432	84.256	86.290	88.524
8	1979	10.790	22.225	33.044	42.824	47.727	55.661	70.476	76.481	85.855	95.318	94.695
9	1980	14.453	21.018	28.027	43.339	50.714	58.518	71.392	84.866	94.860	97.808	96.951
10	1981	14.640	22.427	32.275	44.329	50.504	58.747	63.379	70.145	72.653	83.359	97.803
11	1982	13.197	22.096	33.245	45.153	53.465	59.524	66.643	70.198	75.631	90.603	98.551

RV Mean Length by Age												
-	**year**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
12	1983	10.286	20.167	31.199	43.054	52.926	57.763	65.597	71.479	73.375	79.418	89.582
13	1984	12.000	19.162	30.691	42.124	52.237	60.724	66.228	70.609	75.525	79.122	84.150
14	1985	-	17.949	29.090	40.284	51.241	60.202	66.443	74.178	73.939	79.352	88.934
15	1986	11.000	18.789	27.137	40.318	48.956	55.739	62.097	72.237	76.432	82.807	93.274
16	1987	10.678	19.894	29.540	39.486	48.410	54.076	61.154	67.258	77.817	85.420	83.173
17	1988	9.209	19.679	29.046	40.691	47.754	56.196	62.218	66.709	74.566	79.685	79.725
18	1989	12.000	19.208	30.210	41.728	48.150	56.262	64.043	71.822	75.927	84.644	88.466
19	1990	-	19.893	29.904	40.131	48.292	53.678	56.641	62.279	70.080	76.156	79.092
20	1991	9.545	19.246	29.813	38.959	47.013	53.469	57.436	62.775	68.162	73.697	73.814
21	1992	-	20.659	30.436	40.948	47.381	55.282	61.177	62.353	66.717	73.333	83.899
22	1993	-	-	30.941	41.263	48.045	52.654	62.251	70.577	77.122	80.165	96.023
23	1994	-	19.085	32.169	39.393	48.184	50.210	53.677	59.118	67.978	87.735	79.682
24	1995	-	21.217	29.915	41.958	50.388	56.490	58.211	57.869	62.993	79.584	81.252
25	1996	12.598	20.815	29.965	38.651	44.208	52.910	60.920	61.163	63.290	76.770	74.735
26	1997	12.704	24.080	31.829	40.928	48.199	51.645	60.735	65.424	67.297	67.257	82.507
27	1998	10.553	22.313	32.761	42.652	49.119	53.346	57.593	67.143	77.439	77.203	64.321
28	1999	12.045	22.422	31.414	43.202	51.417	58.905	61.701	66.150	77.565	86.789	76.855
29	2000	13.291	21.968	31.668	40.841	48.847	54.683	60.513	65.258	67.866	81.150	92.708
30	2001	10.555	21.911	33.235	40.625	47.558	51.372	57.434	68.787	77.490	75.019	85.451
31	2002	11.983	21.983	31.762	42.026	50.759	55.052	55.156	67.154	74.635	79.756	73.442
32	2003	10.694	23.720	31.903	42.961	51.806	55.353	58.626	58.717	70.542	72.034	65.514
33	2004	14.043	20.179	33.693	38.886	47.634	60.823	66.304	69.167	67.267	69.619	73.208
34	2005	12.064	25.536	34.197	41.853	48.556	54.483	63.518	67.642	72.294	72.634	99.232
35	2007	11.101	21.152	30.703	38.096	48.893	54.911	55.803	64.916	81.722	91.615	86.911
36	2008	11.678	18.398	26.616	38.521	45.864	53.001	60.154	59.443	66.920	68.191	90.045
37	2009	12.348	19.067	31.343	38.745	46.658	55.013	60.499	63.492	72.265	75.982	83.288
38	2010	11.771	22.706	30.453	40.436	45.635	55.014	65.765	70.945	75.229	81.088	92.596
39	2011	14.005	23.522	30.228	40.082	47.091	49.515	56.133	61.705	73.790	53.200	-
40	2012	11.093	18.593	34.154	41.746	48.056	55.755	53.854	60.961	72.192	73.780	105.000

RV Mean Length by Age												
-	year	1	2	3	4	5	6	7	8	9	10	11
41	2013	12.316	20.375	27.912	41.902	47.663	47.806	53.351	53.981	63.672	55.442	97.000
42	2014	10.607	20.920	30.212	35.045	47.799	53.438	54.494	63.172	65.008	59.320	-
43	2015	11.871	20.897	30.547	39.813	45.042	53.758	56.463	55.977	64.455	72.447	87.000
44	2016	12.168	19.441	29.669	38.635	45.263	48.765	55.685	61.415	57.000	72.422	96.000
45	2017	11.697	19.604	28.219	38.847	44.913	49.102	52.814	53.828	61.674	85.541	72.357
46	2018	12.495	21.772	31.338	38.142	45.287	50.257	57.409	57.039	88.534	60.393	61.056

RV Mean Length by Age											
-	year	12	13	14	15	16	17	18	19	20	21
1	1972	88.337	102.186	98.716	97.385	114.421	114.222	123.559	111.000	141.000	108.000
2	1973	87.585	100.000	93.310	110.000	118.474	116.640	127.763	-	-	-
3	1974	95.645	101.824	111.101	116.000	101.338	131.000	124.000	128.000	-	-
4	1975	107.185	92.254	-	110.000	-	104.000	-	-	131.000	-
5	1976	110.532	-	-	109.309	-	137.000	122.000	143.000	-	-
6	1977	87.945	110.014	82.000	109.465	-	-	133.000	-	132.252	-
7	1978	79.282	82.000	-	92.892	-	113.000	-	147.000	-	-
8	1979	116.000	113.844	106.118	-	-	-	-	-	-	-
9	1980	106.639	110.807	-	113.512	123.501	133.000	-	-	-	-
10	1981	90.225	113.150	101.183	109.000	118.000	122.000	-	-	123.128	-
11	1982	105.173	104.828	96.015	122.995	113.940	-	-	-	-	-
12	1983	93.733	106.567	112.425	116.019	121.084	113.000	132.696	128.514	122.688	123.196
13	1984	98.125	91.113	112.381	-	120.080	-	131.475	-	-	138.000
14	1985	93.033	99.121	112.251	105.739	119.824	121.535	131.000	-	-	136.787
15	1986	93.901	99.861	111.680	112.040	123.167	125.001	-	-	128.000	-
16	1987	89.853	97.115	100.585	108.845	119.275	126.710	125.423	119.217	129.324	125.711
17	1988	87.540	99.606	99.950	111.386	108.149	116.870	130.000	121.000	134.685	-
18	1989	96.609	100.204	100.440	100.703	110.526	120.592	119.259	121.082	113.609	-
19	1990	88.744	86.716	93.047	119.000	114.648	89.000	112.000	120.000	-	-

RV Mean Length by Age											
-	year	12	13	14	15	16	17	18	19	20	21
20	1991	77.139	84.489	84.539	103.760	106.941	104.503	111.893	86.000	-	-
21	1992	81.753	85.000	104.000	94.549	101.000	-	-	-	-	-
22	1993	106.000	97.000	97.000	103.832	118.000	122.000	-	-	-	-
23	1994	90.461	92.810	92.586	-	116.000	100.000	-	-	-	-
24	1995	83.579	97.911	90.724	105.225	-	-	-	-	-	-
25	1996	86.091	-	-	-	-	-	-	-	-	-
26	1998	78.000	-	-	-	-	-	-	-	-	-
27	1999	109.019	65.000	-	-	-	-	-	-	-	-
28	2000	89.052	-	98.000	-	-	-	-	-	-	-
29	2001	96.799	90.669	94.541	93.000	106.787	-	-	-	-	-
30	2002	85.953	93.953	104.000	-	-	-	-	-	-	-
31	2003	86.607	77.052	104.000	106.000	-	-	-	-	-	-
32	2004	73.500	73.000	112.000	109.651	-	-	-	-	-	-
33	2005	103.381	100.177	111.620	106.010	109.064	-	-	-	-	-
34	2007	86.559	103.037	109.907	84.000	102.000	119.000	-	-	-	-
35	2008	94.119	94.040	110.000	-	121.000	-	-	-	-	-
36	2009	87.167	93.890	81.000	-	92.408	-	-	-	-	-
37	2010	103.101	91.000	-	-	-	-	-	-	116.000	-
38	2011	75.463	73.000	108.000	-	-	-	-	-	-	-
39	2012	107.000	-	108.000	111.758	-	-	95.000	-	-	-
40	2013	95.909	-	98.441	-	-	-	-	-	-	-
41	2014	80.000	-	104.000	-	-	-	-	-	-	-
42	2018	96.000	-	-	-	-	-	-	-	-	-

RV Number of Otoliths by Age																						
-	**year**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**
1	1972	2	8	9	16	14	17	26	26	21	18	8	6	3	6	3	4	5	3	1	1	1
2	1973	4	11	11	18	22	10	20	17	27	14	4	4	1	2	1	3	3	5	-	-	-
3	1974	7	12	15	14	20	26	23	24	23	19	7	6	4	6	1	3	1	1	1	-	-
4	1975	6	14	20	26	24	22	24	19	18	9	5	2	3	-	1	-	1	-	-	1	-
5	1976	9	17	21	20	23	20	14	21	8	5	6	2	-	-	2	-	1	1	1	-	-
6	1977	1	6	23	22	27	25	17	13	14	9	2	4	4	1	2	-	-	1	-	2	-
7	1978	-	8	9	20	22	19	18	17	11	8	5	2	2	-	2	-	1	-	1	-	-
8	1979	9	9	14	18	32	33	27	29	15	14	4	1	2	3	-	-	-	-	-	-	-
9	1980	3	15	21	13	23	26	23	28	12	9	10	10	4	-	2	2	1	-	-	-	-
10	1981	2	10	19	17	19	27	31	21	27	11	4	6	4	3	1	2	1	-	-	2	-
11	1982	9	18	13	21	22	21	29	35	21	12	7	3	2	2	2	2	-	-	-	-	-
12	1983	7	13	23	17	25	26	17	32	38	36	30	16	8	6	6	6	1	3	2	2	2
13	1984	1	9	14	19	18	31	29	16	24	29	12	9	5	3	-	3	-	3	-	-	1
14	1985	-	10	17	22	24	23	31	30	18	26	25	28	17	9	3	3	5	2	-	-	2
15	1986	1	8	14	23	28	30	28	33	31	19	15	19	13	9	7	4	3	-	-	1	-
16	1987	4	9	15	17	25	27	33	35	32	17	13	13	17	16	6	6	6	5	2	2	2
17	1988	3	10	17	20	20	30	36	35	30	28	29	25	19	17	14	13	2	1	1	2	-
18	1989	3	12	20	21	21	24	34	38	30	23	31	13	11	7	9	7	5	3	2	2	-
19	1990	-	5	17	22	25	24	25	32	23	20	14	11	8	7	1	3	1	1	1	-	-
20	1991	6	14	14	22	28	26	29	31	30	27	24	12	10	6	7	4	3	2	1	-	-
21	1992	-	6	18	19	26	31	32	26	18	20	10	6	1	1	4	1	-	-	-	-	-
22	1993	-	-	16	21	21	30	28	17	10	4	8	1	1	1	2	1	1	-	-	-	-
23	1994	-	8	14	20	31	26	30	30	10	10	4	6	3	3	-	1	1	-	-	-	-
24	1995	-	3	11	15	25	36	30	37	34	14	10	2	5	6	2	-	-	-	-	-	-
25	1996	10	12	19	22	16	27	41	27	21	10	10	2	-	-	-	-	-	-	-	-	-
26	1997	8	16	18	16	14	16	21	18	11	5	2	-	-	-	-	-	-	-	-	-	-
27	1998	8	13	18	22	21	17	18	33	39	13	5	1	-	-	-	-	-	-	-	-	-
28	1999	8	19	26	19	29	28	27	15	30	29	6	2	1	-	-	-	-	-	-	-	-
29	2000	10	14	22	19	19	24	26	27	18	19	28	11	-	1	-	-	-	-	-	-	-

RV Number of Otoliths by Age																						
-	year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
30	2001	9	13	22	25	18	20	24	23	20	11	12	26	3	3	1	2	-	-	-	-	-
31	2002	10	13	14	22	18	21	18	25	19	15	3	9	12	1	-	-	-	-	-	-	-
32	2003	11	14	15	15	24	27	15	10	14	7	6	3	7	1	1	-	-	-	-	-	-
33	2004	6	14	20	16	21	31	33	18	12	11	13	3	1	1	2	-	-	-	-	-	-
34	2005	10	14	21	19	18	18	26	28	15	3	11	6	2	2	6	9	-	-	-	-	-
35	2007	11	15	22	23	24	20	15	13	23	21	9	7	7	5	1	1	1	-	-	-	-
36	2008	6	14	22	28	25	21	24	16	7	12	10	5	4	1	-	1	-	-	-	-	-
37	2009	6	15	26	23	24	27	26	23	9	4	9	19	10	1	-	2	-	-	-	-	-
38	2010	11	14	17	24	24	24	25	12	6	2	3	7	1	-	-	-	-	-	-	1	-
39	2011	5	16	23	13	25	21	32	15	7	3	-	2	1	1	-	-	-	-	-	-	-
40	2012	10	20	31	29	24	35	28	30	8	8	1	1	-	1	3	-	-	1	-	-	-
41	2013	9	18	20	28	20	14	25	17	17	5	1	2	-	2	-	-	-	-	-	-	-
42	2014	8	12	21	21	21	22	11	27	16	2	-	1	-	1	-	-	-	-	-	-	-
43	2015	6	15	19	26	20	25	18	9	17	3	1	-	-	-	-	-	-	-	-	-	-
44	2016	9	11	20	22	29	14	15	7	1	5	1	-	-	-	-	-	-	-	-	-	-
45	2017	8	15	18	19	26	27	15	10	4	2	2	-	-	-	-	-	-	-	-	-	-
46	2018	11	15	19	19	18	25	35	6	10	2	6	2	-	-	-	-	-	-	-	-	-

Model Estimated Catch Weight-at-Age													
-	year	3	4	5	6	7	8	9	10	11	12	13	14
1	1959	0.518	0.776	1.251	1.973	2.685	3.614	4.502	5.687	6.668	7.737	9.097	12.906
2	1960	0.518	0.776	1.251	1.973	2.685	3.614	4.502	5.687	6.668	7.737	9.097	12.906
3	1961	0.518	0.776	1.251	1.973	2.685	3.614	4.502	5.687	6.668	7.737	9.097	12.906
4	1962	0.518	0.776	1.251	1.973	2.685	3.614	4.502	5.687	6.668	7.737	9.097	12.906
5	1963	0.518	0.776	1.251	1.973	2.685	3.614	4.502	5.687	6.668	7.737	9.097	12.906
6	1964	0.518	0.776	1.251	1.973	2.685	3.614	4.502	5.687	6.668	7.737	9.097	12.906
7	1965	0.518	0.776	1.251	1.973	2.685	3.614	4.502	5.687	6.668	7.737	9.097	12.906
8	1966	0.518	0.776	1.251	1.973	2.685	3.614	4.502	5.687	6.668	7.737	9.097	12.906
9	1967	0.518	0.776	1.251	1.973	2.685	3.614	4.502	5.687	6.668	7.737	9.097	12.906

Model Estimated Catch Weight-at-Age													
-	**year**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
10	1968	0.518	0.776	1.251	1.973	2.685	3.614	4.502	5.687	6.668	7.737	9.097	12.906
11	1969	0.518	0.776	1.251	1.973	2.685	3.614	4.502	5.687	6.668	7.737	9.097	12.906
12	1970	0.518	0.776	1.251	1.973	2.685	3.614	4.502	5.687	6.668	7.737	9.097	12.906
13	1971	0.518	0.776	1.251	1.973	2.685	3.614	4.502	5.687	6.668	7.737	9.097	12.906
14	1972	0.518	0.776	1.251	1.973	2.685	3.614	4.502	5.687	6.668	7.737	9.097	12.906
15	1973	0.518	0.776	1.251	1.973	2.685	3.614	4.502	5.687	6.668	7.737	9.097	12.906
16	1974	0.459	0.674	1.080	1.749	2.387	3.177	3.988	4.839	5.753	6.967	8.265	12.030
17	1975	0.533	0.791	1.228	1.795	2.440	3.291	4.015	5.221	5.934	7.019	8.550	12.343
18	1976	0.559	0.945	1.484	2.259	2.999	4.155	5.189	6.454	7.673	8.522	9.940	14.007
19	1977	0.510	0.734	1.321	2.033	2.770	3.648	4.663	5.898	6.845	8.082	9.115	13.101
20	1978	0.529	0.735	1.144	2.026	2.830	3.800	4.655	6.026	7.135	8.094	9.615	13.051
21	1979	0.514	0.711	1.065	1.675	2.662	3.662	4.678	5.871	7.184	8.379	9.527	13.228
22	1980	0.522	0.790	1.163	1.710	2.365	3.700	4.956	6.345	7.348	8.709	9.945	13.452
23	1981	0.559	0.845	1.321	1.851	2.381	3.250	4.901	6.383	7.640	8.751	10.287	14.283
24	1982	0.514	0.806	1.215	1.816	2.294	2.871	3.766	5.516	6.795	8.015	9.117	13.388
25	1983	0.599	0.891	1.421	1.982	2.601	3.160	3.913	5.027	6.956	8.264	9.568	13.526
26	1984	0.684	1.044	1.500	2.193	2.894	3.903	4.913	5.947	7.109	9.293	10.649	14.408
27	1985	0.575	0.820	1.238	1.793	2.575	3.448	4.851	5.860	6.711	7.777	10.216	14.138
28	1986	0.503	0.745	1.143	1.717	2.306	3.261	4.535	5.911	6.678	7.374	8.587	13.669
29	1987	0.522	0.734	1.193	1.707	2.316	3.104	4.416	5.612	6.816	7.342	8.101	12.581
30	1988	0.549	0.758	1.101	1.673	2.232	3.106	4.168	5.597	6.641	7.628	8.246	11.874
31	1989	0.513	0.794	1.196	1.751	2.476	3.296	4.434	5.531	6.859	7.637	8.800	11.672
32	1990	0.526	0.751	1.306	1.897	2.465	3.256	4.149	5.260	6.246	7.321	8.220	11.153
33	1991	0.510	0.692	1.128	1.889	2.515	3.186	4.389	5.538	6.876	7.625	8.999	11.994
34	1992	0.514	0.674	1.060	1.662	2.484	3.239	4.451	6.256	7.706	8.804	9.884	13.421
35	1993	0.548	0.814	1.264	1.760	2.175	2.966	3.936	5.152	6.848	7.635	8.922	12.136
36	1994	0.473	0.769	1.392	1.834	2.107	2.588	3.786	4.949	6.350	7.532	8.670	11.950
37	1995	0.700	0.744	1.561	2.214	2.413	2.710	3.517	5.012	6.387	7.303	9.082	12.309
38	1996	0.703	0.848	1.235	1.956	2.521	2.856	3.522	4.477	6.320	7.341	8.859	12.622

Model Estimated Catch Weight-at-Age													
-	year	3	4	5	6	7	8	9	10	11	12	13	14
39	1997	0.589	0.897	1.281	1.509	2.334	3.086	3.590	4.121	5.090	6.555	7.866	11.307
40	1998	0.599	0.988	1.681	2.003	2.213	3.180	4.045	4.300	4.738	5.341	6.927	10.054
41	1999	0.648	0.909	1.544	2.266	2.547	2.686	3.945	4.987	5.351	5.670	6.527	10.284
42	2000	0.622	0.927	1.272	1.985	2.721	2.949	3.201	4.757	6.179	6.560	7.064	10.538
43	2001	0.678	1.067	1.488	1.909	2.605	3.339	3.562	3.713	5.565	7.143	7.586	10.331
44	2002	0.602	1.043	1.537	1.988	2.252	2.989	3.863	3.965	4.181	6.221	7.904	10.145
45	2003	0.624	0.953	1.537	2.080	2.366	2.617	3.570	4.517	4.793	5.108	7.556	10.761
46	2004	0.654	0.962	1.402	2.084	2.492	2.764	3.089	4.203	5.493	5.850	6.249	11.070
47	2005	0.675	0.973	1.382	1.837	2.428	2.844	3.205	3.583	4.824	6.206	6.788	10.490
48	2006	0.689	1.036	1.486	1.888	2.184	2.775	3.329	3.813	4.121	5.400	7.108	9.990
49	2007	0.708	1.047	1.531	1.995	2.277	2.616	3.506	4.464	5.065	5.332	7.107	10.795
50	2008	0.671	0.988	1.406	1.945	2.212	2.445	2.835	4.020	5.093	5.568	6.146	10.597
51	2009	0.826	1.023	1.518	2.080	2.452	2.644	2.889	3.642	5.317	6.362	7.220	11.009
52	2010	0.795	1.103	1.357	1.923	2.236	2.552	2.800	3.350	4.461	5.996	7.365	10.766
53	2011	0.804	1.006	1.392	1.632	2.030	2.273	2.551	2.794	3.257	3.667	4.911	8.004
54	2012	0.826	1.046	1.420	1.920	1.985	2.313	2.623	2.975	3.281	3.360	3.846	7.187
55	2013	0.760	1.105	1.482	1.772	2.068	2.087	2.480	2.821	3.273	3.367	3.694	6.927
56	2014	0.857	1.112	1.745	2.045	2.226	2.628	2.638	3.207	3.775	4.141	4.544	7.903
57	2015	0.805	1.139	1.541	2.098	2.357	2.619	3.070	3.234	4.101	4.614	5.294	8.475
58	2016	0.709	1.061	1.515	1.811	2.276	2.501	2.827	3.487	3.833	4.595	5.307	8.644
59	2017	0.598	0.883	1.349	1.781	1.936	2.387	2.653	3.043	3.870	3.989	4.880	8.136

Model Estimated Stock Weight-at-Age															
-	year	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	1959	0.016	0.093	0.301	0.692	1.251	1.841	2.48	3.21	4.23	5.48	6.70	8.48	9.90	14.68
2	1960	0.016	0.093	0.301	0.692	1.251	1.841	2.48	3.21	4.23	5.48	6.70	8.48	9.90	14.68
3	1961	0.016	0.093	0.301	0.692	1.251	1.841	2.48	3.21	4.23	5.48	6.70	8.48	9.90	14.68
4	1962	0.016	0.093	0.301	0.692	1.251	1.841	2.48	3.21	4.23	5.48	6.70	8.48	9.90	14.68

Model Estimated Stock Weight-at-Age															
-	**year**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
5	1963	0.016	0.093	0.301	0.692	1.251	1.841	2.48	3.21	4.23	5.48	6.70	8.48	9.90	14.68
6	1964	0.016	0.093	0.301	0.692	1.251	1.841	2.48	3.21	4.23	5.48	6.70	8.48	9.90	14.68
7	1965	0.016	0.093	0.301	0.692	1.251	1.841	2.48	3.21	4.23	5.48	6.70	8.48	9.90	14.68
8	1966	0.016	0.093	0.301	0.692	1.251	1.841	2.48	3.21	4.23	5.48	6.70	8.48	9.90	14.68
9	1967	0.016	0.093	0.301	0.692	1.251	1.841	2.48	3.21	4.23	5.48	6.70	8.48	9.90	14.68
10	1968	0.016	0.093	0.301	0.692	1.251	1.841	2.48	3.21	4.23	5.48	6.70	8.48	9.90	14.68
11	1969	0.016	0.093	0.301	0.692	1.251	1.841	2.48	3.21	4.23	5.48	6.70	8.48	9.90	14.68
12	1970	0.016	0.093	0.301	0.692	1.251	1.841	2.48	3.21	4.23	5.48	6.70	8.48	9.90	14.68
13	1971	0.016	0.093	0.301	0.692	1.251	1.841	2.48	3.21	4.23	5.48	6.70	8.48	9.90	14.68
14	1972	0.018	0.099	0.299	0.655	1.162	1.693	2.30	3.13	4.32	5.68	6.85	8.46	9.72	14.35
15	1973	0.016	0.092	0.290	0.628	1.097	1.613	2.17	2.79	3.80	5.14	6.34	7.92	9.15	13.67
16	1974	0.015	0.091	0.298	0.677	1.181	1.721	2.34	2.98	3.84	5.11	6.47	8.23	9.53	14.15
17	1975	0.015	0.091	0.313	0.739	1.361	1.964	2.64	3.39	4.32	5.41	6.72	8.72	10.23	15.06
18	1976	0.017	0.091	0.304	0.759	1.452	2.216	2.96	3.78	4.88	6.05	7.11	9.08	10.88	16.16
19	1977	0.016	0.087	0.272	0.654	1.323	2.111	3.01	3.83	4.95	6.23	7.25	8.79	10.42	16.10
20	1978	0.014	0.079	0.248	0.555	1.063	1.806	2.69	3.65	4.72	5.94	7.03	8.49	9.59	15.21
21	1979	0.015	0.083	0.261	0.599	1.068	1.754	2.78	3.92	5.33	6.66	7.83	9.56	10.68	16.09
22	1980	0.015	0.089	0.276	0.632	1.165	1.767	2.69	4.00	5.59	7.33	8.54	10.34	11.69	16.84
23	1981	0.015	0.085	0.276	0.622	1.122	1.716	2.37	3.33	4.87	6.61	8.14	9.80	11.07	15.92
24	1982	0.015	0.084	0.278	0.658	1.181	1.781	2.50	3.22	4.51	6.42	8.16	10.35	11.58	16.37
25	1983	0.014	0.078	0.253	0.606	1.140	1.700	2.36	3.11	4.00	5.46	7.34	9.64	11.42	16.00
26	1984	0.013	0.074	0.246	0.580	1.104	1.741	2.39	3.12	4.11	5.16	6.66	9.23	11.27	16.41
27	1985	0.013	0.071	0.233	0.558	1.039	1.666	2.42	3.14	4.12	5.31	6.31	8.40	10.82	16.73
28	1986	0.013	0.070	0.220	0.526	0.985	1.544	2.28	3.13	4.10	5.25	6.39	7.85	9.73	16.60
29	1987	0.012	0.069	0.221	0.500	0.924	1.465	2.10	2.92	4.03	5.09	6.10	7.66	8.77	15.53
30	1988	0.012	0.067	0.223	0.512	0.895	1.410	2.05	2.76	3.83	5.08	5.99	7.44	8.70	14.54
31	1989	0.013	0.069	0.226	0.542	0.966	1.438	2.08	2.84	3.84	5.15	6.37	7.78	8.96	14.45
32	1990	0.013	0.068	0.204	0.479	0.875	1.307	1.77	2.39	3.28	4.30	5.39	6.96	7.93	12.69
33	1991	0.013	0.072	0.209	0.445	0.794	1.240	1.69	2.15	2.95	3.92	4.81	6.28	7.57	11.79

Model Estimated Stock Weight-at-Age															
-	**year**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
34	1992	0.013	0.074	0.243	0.503	0.821	1.268	1.82	2.35	3.06	4.08	5.11	6.53	7.93	12.56
35	1993	0.013	0.074	0.244	0.570	0.914	1.274	1.82	2.48	3.30	4.22	5.29	6.87	8.16	13.23
36	1994	0.013	0.071	0.222	0.516	0.927	1.243	1.59	2.15	3.02	3.96	4.74	6.19	7.50	12.33
37	1995	0.014	0.074	0.225	0.501	0.902	1.377	1.70	2.05	2.85	3.92	4.78	5.92	7.17	12.06
38	1996	0.014	0.075	0.231	0.500	0.855	1.316	1.86	2.19	2.75	3.73	4.76	6.00	6.89	11.77
39	1997	0.015	0.080	0.249	0.548	0.920	1.351	1.93	2.61	3.17	3.86	4.86	6.41	7.44	12.03
40	1998	0.016	0.084	0.256	0.573	0.992	1.423	1.95	2.68	3.74	4.41	4.98	6.47	7.86	12.36
41	1999	0.016	0.090	0.272	0.595	1.056	1.553	2.08	2.74	3.86	5.22	5.71	6.68	7.99	12.86
42	2000	0.015	0.087	0.271	0.583	0.998	1.490	2.04	2.62	3.54	4.84	6.11	6.95	7.51	12.29
43	2001	0.014	0.081	0.267	0.588	0.992	1.433	1.99	2.62	3.44	4.47	5.70	7.44	7.80	11.69
44	2002	0.014	0.078	0.255	0.594	1.033	1.464	1.95	2.59	3.45	4.33	5.24	6.87	8.26	11.30
45	2003	0.014	0.079	0.245	0.564	1.036	1.513	1.98	2.51	3.36	4.28	5.02	6.29	7.62	11.20
46	2004	0.014	0.082	0.259	0.564	1.027	1.611	2.18	2.72	3.51	4.52	5.41	6.59	7.63	11.76
47	2005	0.014	0.083	0.265	0.595	1.029	1.597	2.32	3.00	3.85	4.85	5.93	7.36	8.27	12.52
48	2006	0.013	0.074	0.247	0.562	1.001	1.473	2.12	2.95	3.95	4.92	5.84	7.36	8.44	12.41
49	2007	0.013	0.068	0.223	0.529	0.952	1.451	1.98	2.74	3.94	5.10	5.98	7.31	8.54	12.50
50	2008	0.012	0.066	0.198	0.459	0.844	1.301	1.83	2.37	3.36	4.64	5.66	6.85	7.78	11.70
51	2009	0.014	0.070	0.218	0.466	0.837	1.336	1.89	2.51	3.34	4.52	5.85	7.30	8.16	11.95
52	2010	0.015	0.079	0.234	0.516	0.853	1.329	1.95	2.62	3.57	4.55	5.81	7.73	8.90	12.57
53	2011	0.013	0.079	0.239	0.500	0.843	1.186	1.69	2.35	3.24	4.25	5.14	6.78	8.37	12.08
54	2012	0.013	0.072	0.244	0.526	0.846	1.225	1.58	2.15	3.08	4.10	5.12	6.39	7.80	12.16
55	2013	0.013	0.068	0.209	0.500	0.822	1.124	1.50	1.86	2.61	3.63	4.61	5.96	6.91	11.39
56	2014	0.013	0.069	0.211	0.460	0.846	1.199	1.52	1.96	2.52	3.43	4.51	5.90	7.04	11.31
57	2015	0.013	0.070	0.215	0.467	0.777	1.240	1.63	1.99	2.64	3.28	4.22	5.73	6.91	11.21
58	2016	0.013	0.068	0.209	0.459	0.762	1.101	1.63	2.07	2.61	3.35	3.93	5.23	6.58	10.89
59	2017	0.013	0.069	0.206	0.451	0.753	1.090	1.47	2.09	2.73	3.33	4.03	4.89	6.02	10.53
60	2018	0.014	0.074	0.226	0.484	0.815	1.192	1.61	2.08	3.05	3.80	4.33	5.42	6.06	10.68